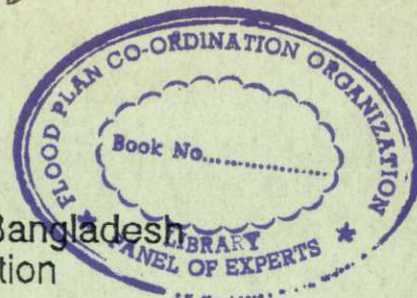


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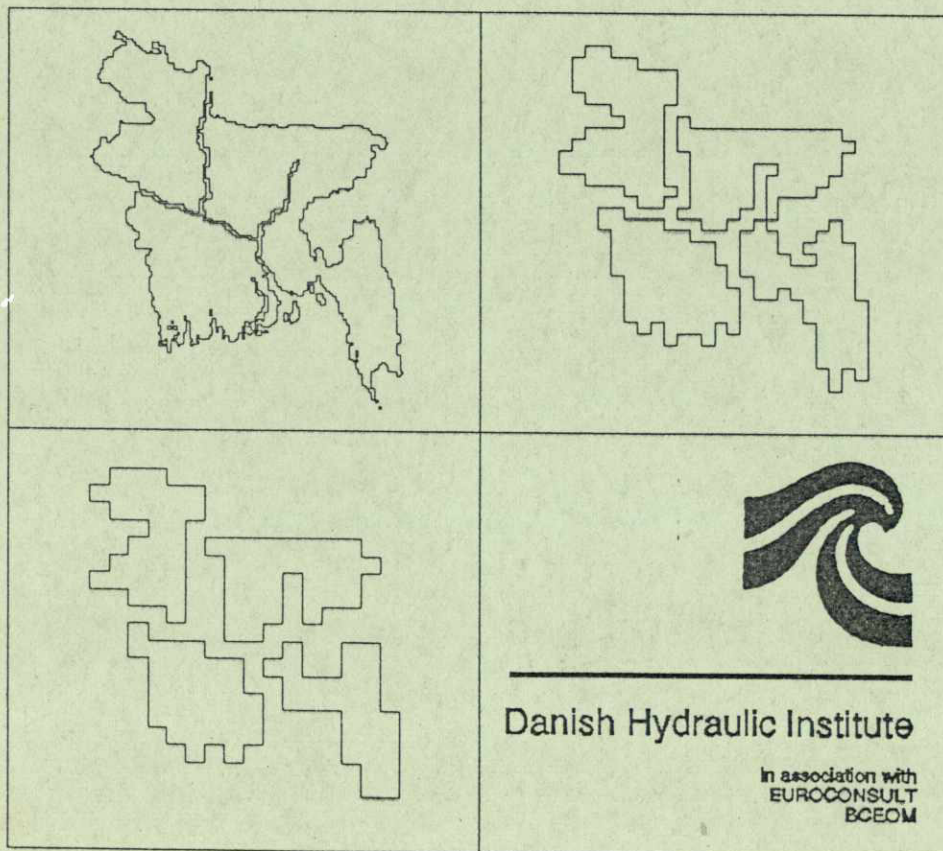
Government of the People's Republic of Bangladesh
Flood Plan Coordination Organization

FAP25 : FLOOD MODELLING & MANAGEMENT

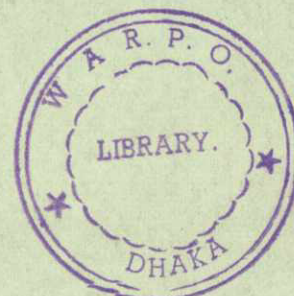
FLOOD MANAGEMENT MODEL

BN-818
A-972

INCEPTION REPORT
April 1993



Governments of:
Denmark, The Netherlands, France



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FAP 25: Flood Modelling and Management

Flood Management Model

Inception Report

MFV-2406
29-02



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ACRONYMS / ABBREVIATIONS

AML	ARC/INFO Macro Language
ARC/INFO	Geographic Information System Package
BADC	Bangladesh Agricultural Development Corporation
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agricultural Research Institute
BAU	Bangladesh Agricultural University
BIWTA	Bangladesh Inland Water Transport Authority
BRDB	Bangladesh Rural development Board
BRI	Bangladesh Rice Research Institute
BWDB	Bangladesh Water Development Board
CAT	Coordination Advisory Team.
CFD	Caisse Francaise Developpement
CHE	Computational Hydraulic Engineer
CIDA	Canadian International Development Agency
CPP	Compartmentalization Pilot Project.
DAE	Department of Agricultural Extension
DANIDA	Danish International Development Assistance
DEM	Digital Elevation Model
DHI	Danish Hydraulic Institute
DOE	Department of Environment
DOF	Directorate of Fisheries
EIP	Early Implementation Project (Dutch-assisted FCD Project)
FAP	Flood Action Plan
FCD	Flood Control and Drainage
FCDI	Flood Control, Drainage, and Irrigation
FF&WC	Flood Forecasting & Warning Centre
FFW	Food-For-Work
FHS	Flood Hydrology Study
FMM	Flood Management Model
FPCO	Flood Plan Coordination Organisation (under MIWDFC)
GIS	Geographic Information System
GM	General Model
GOB	Government of Bangladesh
GPS	Geopositional Satellite
HD	Hydrodynamic
HYV	High Yielding Variety
HP	Hewlett Packard
ISPAN	Irrigation Support Project for Asia and the Near East
JPPS	Jamalpur Priority Piltto Study
LGEB	Local Government Engineering Bureau
LGED	Local Government Engineering Directorate
MIKE11-GIS	River Modelling - Geographic Information System Interface
MIWDFC	Ministry of Irrigation, Water Development and Flood Control
MOA	Ministry of Agriculture
MPO	Master Plan Organisation (under MIWDFC),now WARPO

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NAM	Rainfall Runoff Model (Danish Abbreviation)
NCRM	North Central Regional Model
NCRS	North Central Regional Study
NGO	Non-Governmental Organization
O&M	Operation and Maintenance
POE	Panel of Experts
R&H	Roads and Highways
RRI	River Research Institute
SPARRSO	Space Research and Remote Sensing Organization
SSWCSIII	Small Scale Water Control Structures III Project
SRP	Systems Rehabilitation Project
SWH	Surface Water Hydrology
SWMC	Surface Water Modelling Centre
SWSMP	Surface Water Simulation Modelling Program
TCM	Tangail Compartment Model
TL	Team Leader
TIN	Triangular Irregular Network
TOR	Terms of Reference
UNDP	United Nations Development Program
USAID	United States Agency for International Development
UX	UNIX
WARPO	Water Resources Planning Organization
WBS	Work Breakdown Structure
WMO	World Meteorological Organisation
WS	Work Station

EXECUTIVE SUMMARY

The Flood Action Plan (FAP) aims at the identification, planning, design and construction of high priority flood control projects which are technically, economically, environmentally and socially feasible. The plan follows a staged approach and comprises in total 26 main components and supporting activities. The Flood Management Model (FMM) development is undertaken under the FAP component No. 25.

In undertaking several of the components of FAP, mathematical river models have been developed. These models are indispensable decision support tools for flood management in Bangladesh. They will be central to the optimal operation and management of flood control structures. In addition, they can be employed in the implementation of a programme of nonstructural measures such as flood forecasting, flood warning and disaster management. However, based on the capabilities of the existing models and flood management needs, a gap has been identified which has to be bridged by a dedicated management tool.

The Flood Management Model (FMM) has, therefore, been conceived as a decision support tool which integrates the MIKE 11 based flood modelling system with Digital Elevation Models. Geographic Information System (GIS) technology has been shown by FAP 19 to be a viable tool for managing DEMs in addition to providing advanced graphical and analysis features. The FMM will be developed to provide a decision support tool for the planning, operation and management of flood control and drainage systems on compartment level as well as on regional and national levels.

Key features of the FMM will be flood mapping of MIKE 11 output as flood extents, flood depths and flood duration; assessing impacts and damages from flooding; simulating structure operations and assisting in flood forecasting.

The Compartmental Pilot Project (CPP) at Tangail is chosen for the application of FMM at Compartment level. The regional FMM will be applied to the North Central Region in conjunction with the NCRM Model developed at SWMC. The national level FMM will be based on the General Model developed at SWMC.

The development, application and demonstration of the FMM is being carried under the following main categories:

Management.	Management of the project and coordination with relevant agencies.
FMM Development.	Development of the FMM tool.
FMM Application.	Demonstration of the developed technology by applying to National, Regional and Compartment Levels.
Knowledge Transfer.	Organisation of workshops, and documentation, publication and dissemination of reports and training materials.

The FMM project started on 19th October 1992 and is scheduled to be completed within a period of two years. The Project is organised into seven distinct activities (see table below), each having

(v)

specific objectives. An activity itself is made up of a number of tasks which in turn are made up of a number of sub-tasks.

The activities represent the seven main areas of work: Management; FMM development; FMM application at national, regional and sub-regional levels; workshops and documentation.

Summary of Work Programme Activities

Code	Activity	Description
100	Management	Administration, progress monitoring and ensuring all activities, tasks and sub-tasks are completed on-time.
200	FMM Development	Development of the FMM.
300	FMM GM Application	Application of the FMM on a national level using the General Model.
400	FMM NCRM Application	Application of the FMM on a regional level using the North Central Regional Model.
500	FMM TCM Application	Application of the FMM on a sub-regional level using the Tangail Compartment Model.
600	Workshops and Trainings	Organisation and management of workshops and Trainings.
700	Reporting	Documentation, publication and dissemination of reports and training material.

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1. INTRODUCTION

1.1 Background

In the past, floods in Bangladesh have caused widespread damage to physical infrastructure and the national economic progress. The resulting international concern led to the Flood Action Plan (FAP). Donors from Denmark, France, the Netherlands and the United Kingdom responded positively by participating in the execution of the FAP Component No 25 : "Flood Modelling and Management. The Danish International Development Assistance (DANIDA) has supported FAP 25 as the lead donor.

The FAP 25 - Flood Modelling and Management Project which started in October 1990 has three components. The Flood Hydrology Study (FHS) is designed to establish the hydrological basis for engineering design criteria along the major rivers and to develop common modelling standards and techniques for the FAP studies. A Coordination Advisory Team (CAT) has been set up to ensure consistency and compatibility in modelling, and to coordinate development of models for FAP at the Surface Water Modelling Center (SWMC). The third component is the development of a Flood Management Model (FMM) and demonstration of its applicability.

The Flood Plan Coordination Organization (FPCO) under the Ministry of Irrigation, Water Development and Flood Control (MIWDFC) is the implementing agency of the FMM component. DANIDA is the coordinating donor agency on behalf of the contributing donors, Denmark, France and the Netherlands. The Dutch support to the project is being provided through FAP 20 - the Compartmentalization Pilot Project (CPP). The Danish Hydraulic Institute (DHI) in association with EUROCONSULT and BCEOM, French Engineering Consultants, are undertaking the FMM study.

The FMM is conceived as a decision support tool which integrates the MIKE 11 based flood modelling system with advanced graphical displays and analysis using the Digital Elevation Models (DEM) and the Geographic Information System (GIS). FMM will assist in flood management including planning and operation of flood control and drainage systems.

While the general concepts of FMM and methodology of the study will be guided by the Terms of Reference (TOR) as given in Appendix A, and the DHI proposal approved by DANIDA and GOB, this Inception Report lays out the actual plan of action for the project.

1.2 Objectives

The objective of the FMM is to provide a management tool to assist in prediction and analysis of the behaviour of floods and the design and operation of flood control structures to limit loss of life and damage to agriculture, infrastructure, etc. during floods. The MIKE 11 based simulation models developed at SWMC provide the basis for developing such tools; additional features are required to make them operational for flood management purposes. The objectives of the present study shall be seen in coordination with other on going modelling activities in Bangladesh, in particular those under the FAP. The overall objectives are laid out as follows.

- To achieve in the long-term an on-line flood management. The FMM will extensively use DEMs and GIS graphical input and analysis functions to facilitate rapid assimilation and dissemination of information. It will graphically indicate river water levels, areas and depths of inundation and effects of operations. A coupling with GIS will allow direct determination of the impact in terms of potential crop and fisheries damage, flooding of towns and villages, infrastructure disruption, etc. including a graphical overview of these conditions.
- To couple the simulation models with logical rules for operation (of sluice gates and similar devices) and optimization routines, which can relate the gate openings or pump operations to the prevailing hydrological and hydraulic conditions.
- To integrate the developed technology with other activities, and apply it on a test basis on a National, Regional and Compartment level.
- To present the developed technology to GOB authorities and other potential users, and identify and implement required modifications.

1.3 Project Tasks

The development, application and demonstration of the FMM is being carried under the following activity components:

Management.	Management of the project and coordination with relevant agencies.
FMM Development.	Development of the FMM tool.
FMM Application.	Demonstration of the developed technology by applying to National, Regional and Compartment Levels.
Knowledge Transfer.	Organisation of workshops and trainings, and documentation, publication and dissemination of reports and training materials.

1.4 Inception Report

This Inception Report describes the overall approach being followed and the resources required to achieve the project objectives. Chapter 2 presents the output of the initial system analysis carried out to assess the user needs and existing capabilities. It lays out the foundation on the future requirements and/or expectations from FMM. Chapter 3 describes the concepts of FMM including the specifications and tasks of the several conceptualised modules. The applications of FMM for demonstration as well as for use as a prototype tool in flood management are described in Chapter 4. Chapter 5 sets forth the FMM work plan, including the work breakdown structure, project implementation schedule, professional resource allocation and logistics/equipment requirements.

The TOR for the FMM study is enclosed as Appendix A. Appendix B shows the job

descriptions of profession resources. Appendix C describes the administrative arrangements and logistics involved in the project. Appendix D presents the inventory of data availability for the North Central Region and a plan of additional data collection. The findings from the first workshop is presented in Appendix E.

1.5 Terms of Reference (TOR)

References are made to the TOR at appropriate places in the Inception Report. However, a few comments on the TOR are included in this section.

- The First Workshop

The First Workshop was conducted after the draft Inception Report, but findings are reported in the revised Inception Report. This was done on the recommendation of the Panel of Experts (POE)/FPCO and the CAT so that some of the members could participate in the Workshop. The co-chairmen and members of POE and one member of CAT, who participated actively in the Workshop contributed to the success of the Workshop. Also the draft inception report was presented in the Workshop and useful comments and feedback were received from the participants.

- Upgrading of NCR Model

According to the TOR, NCR-FMM will be based on the North Central Regional Model developed by SWMC. However, as described in Section 4.3 a restructuring of the model will be necessary for FMM application.

- Activities of FCD Engr -I and CHE

In view of the upgrading of NCRM FCD Engineer -I will be fully involved in the NCR-FMM. The Computational Hydraulic Engineer (CHE) will advise on the quasi 2-dimensional modelling approach. The CHE will now be fully responsible for the GM-FMM.

- Digital Elevation Models

The DEM's for the north central region and Tangail compartment made available by FAP 19 are not updated with the latest available information from FAP 18. FMM applications will be based on updated DEMs if these are made available by FAP 19 before the end of 1993.

FAP 25 has started a field survey program in the western part of the north central region to incorporate the location of major structures (embankments), offtakes of important channels and Khals etc in the DEM. Details of embankments (profiles) are also being collected for the tangail compartment in collaboration with FAP 20.

From the modelling point of view as well as from FMM application, it is considered sufficient to use the DEM for the eastern part of the NCR as developed by FAP 19. Incorporation of breaklines, e.g., embankments etc into the DEM is considered to be more important for realistic flood mapping. Hence, it is proposed to use the funds allocated to digitizing the old topo maps in obtaining more recent information on rivers and channels and important infrastructure in the sub-region.

Why?
FAP 15
why not from
FAP 3 or FAP 20

Training & Demonstrations

The TOR does not specify the need for a formal training under FMM. However, FAP25 have planned a consolidated training program on flood modelling and management for senior officers of FPCO and BWDB Hydrology. DANIDA has agreed to finance such a program as a separate activity. *Why?*

The TOR also mentions that various stages of FMM be made available to SWMC for use in their training programs. Since SWSMP-II is at the final stage, no training programs are planned for the remaining part of the project. However, FAP 25 will collaborate with SWMC to obtain feedback on the usefulness of FMM during the initial period of the proposed SWSMP-III project.

Short Term Specialists

The TOR (Annex-1, job description) mentions that the areas that may be covered by expatriate short term specialists which will be brought in as and when required, include: flood management, GIS, economy, environment. Two m-m will be financed by the Netherlands through FAP 20 and four m-m by Denmark. While the Dutch short term specialists will mainly be working during the application phase (Compartmental FMM) the short term specialists supported by DANIDA will mainly be required during the FMM development phase. *It* has been felt necessary to reconsider the areas of expertise of the short term specialists in order to develop the specialised features in the FMM. These include a coupling of the NAM and Mike11 modules for modelling the effect of local rainfall in flood plain flooding, a composite structure operation module, an optimization module for structure operation, embankment breach simulation etc. Considering the expertise available with the long term experts at the project, a revised job description is given in Appendix B and the short term specialists have been identified as given in Appendix C. *Is there any change in total m-m?*

2. FLOOD MANAGEMENT MODEL (FMM)

2.1 Introduction

The Flood Management Model (FMM) will be developed as a decision support tool in the management of Bangladesh's rivers and floodplains.

The FMM will be capable of producing detailed maps of flood extent and flood impact. making flood management decisions will be more sound, easier and more readily accepted.

Flood control and drainage (FCD) structure operations will be addressed. A structure control system will be developed to help optimise operation strategies. The system will also be designed for use on site and will be able to be modified to represent structure failures and maintenance activities.

A flood forecasting component of the FMM will endeavour to use FMM features during a flood forecasting session.

To achieve these goals the FMM will utilise the latest in Geographic Information Systems (GIS) alongwith an upgrading of MIKE 11's structure operation routines. A data base link between MIKE 11 and the GIS will be used to facilitate easy transfer of data.

The data input to the GIS will be a digital elevation model (DEM) of the ground terrain and the output from MIKE 11 simulations. Other inputs will be information on agriculture, fisheries and infrastructure.

Key features of the FMM will be flood mapping of MIKE 11 output as flood extents, flood depths and flood duration; assessing impacts and damages from flooding; simulating structure operations and assisting in flood forecasting.

The main users of the FMM will be professionals working on FAP projects, SWMC and other associated bodies. Some components of the FMM will also be orientated towards non-technical users such as on-site structure operators.

2.2 User Needs Assessment

Interviews with other FAP project personnel and staff of Government and non-Government organisations (Ref. 1) provided insight as to what might be useful features of the FMM. The findings from these interviews have been summarised in Table 2.1.

Participants of the First Workshop also provided useful feedback on the proposed features described in this report. Summaries of the four working group discussions are presented in Appendix E. Most of these have been taken into consideration while designing the various tasks of FMM development. However, as clearly mentioned in the TOR, the FMM activities will be focussed to the development of a conceptual tool as a first step in flood management and its applicability will be demonstrated through examples in the national, regional and compartmental levels.

Table 2.1 Summary of Interviews on FMM

FMM Feature	FAP1	FAP2	FAP3	FAP5	FAP6	FAP8A	FAP10	FAP12	FAP13	FAP19	wDB	SWMC	FPCO	BUET	BARC	LGE	B	DofE	SPARSS	Roads	Agric
Water Level & Ground Profiles	•																				
Flood Maps	•	•	•	•	•	•				•						•				•	•
Flood Depth/Phase Maps		•		•						•						•				•	•
Flood Duration Maps			•	•												•					•
Flood Impact Maps	•	•		•		•				•											•
Flood Damage Maps			•	•								•		•							
Flooded Area Curves		•	•	•																	
Cropping Patterns		•		•																	
Satellite Imagery						•													•		
Design Water Level Statistics								•								•				•	
Flood Xorecasting										•				•							
Structure Operations								•		•			•	•							
Tool for EIA			•	•		•		•							•			•		•	
Usable by Non-Modellers	•	•												•							

2.3 Assessment of MIKE11 for FMM Application

For the FMM application at a national, regional and compartment level, MIKE11 is regarded as satisfactory and usable within its existing capabilities. However, the following recommendations for MIKE11 are proposed if it is to be applied with improved performance. Assessment of the Mike11 system for general flood modelling in Bangladesh has been done by CAT (Ref. 10).

- (i) Modelling of structures comprising several different FCD structures or where different operation routines are to be modelled for the gates of a control structure could be simplified by combining all structures at a single Q-point, and thus remove the necessity of having a parallel branch for each structure.
- (ii) Graphic and tabular output comparing different simulations for making impact assessments of alternative development options is needed.
- (iii) A routine to model the interaction between rainfall-runoff calculated by NAM and floodplain inundation calculated by MIKE11 would be beneficial for modelling flooding by local rainfall.
- (iv) The on-line control of structure operations is cumbersome and difficult, especially for those unfamiliar with MIKE11. This would best be overcome by a simple interface designed for structure operation staff.
- (v) Modelling of embankment breaching may be made using the dambreak module, however, there is an "overkill" and could be greatly simplified.

The modelling of floodplains separately to rivers is foreseen to be an important aspect of the FMM application. In Bangladesh MIKE11 has not typically been used in this manner, because of restrictions on model size (computer limitations), shortage of data and other reasons. MIKE11 is, however, well suited to the quasi 2-D floodplain modelling.

2.4 Assessment of ARC/INFO for FMM Application

PC-ARC/INFO was found to be suitable for most of FAP19's needs, except for raster based analysis. FAP25 has elected to use workstation ARC/INFO which is a much more powerful GIS and has advanced raster based analysis with its GRID module.

DHI has used ARC/INFO for development of MIKE11-GIS and has found it to be highly suited as a GIS medium for river and floodplain modelling.

ARC/INFO is also very good for prototyping and for ultimately defining the functionality needed for the FMM.

The main disadvantage of ARC/INFO is its cost. If the FMM is to be downloaded to numerous other sites then it would be recommended to incorporate relevant FMM features into a less expensive GIS.

2.5 Design Specifications

The specifications for the design of the FMM will encompass the basic features described in the previous section on user needs. It is not possible to incorporate all of the detail of all the features desired, however, most will be addressed and developed to some usable form.

The design of the FMM has been based on the themes described in Table 2.2 and illustrated in Figure 2.1.

Table 2.2 FMM Design Themes

Category	Description
River and Floodplain Modelling	The mathematical modelling of river and floodplain hydraulics, including catchment runoff and tidal effects.
FCD Structure Operations	The simulation of operation strategies and on-line operation of FCD structures, including the effects of structure maintenance and failures.
Impact Assessment	The planning and design of flood mitigation proposals based on assessments of their impact on flooding, agriculture, fisheries, socio-economics and infra-structure.
Flood Forecasting	The forecasting of flood levels to facilitate flood warnings and measures to reduce flood damage.

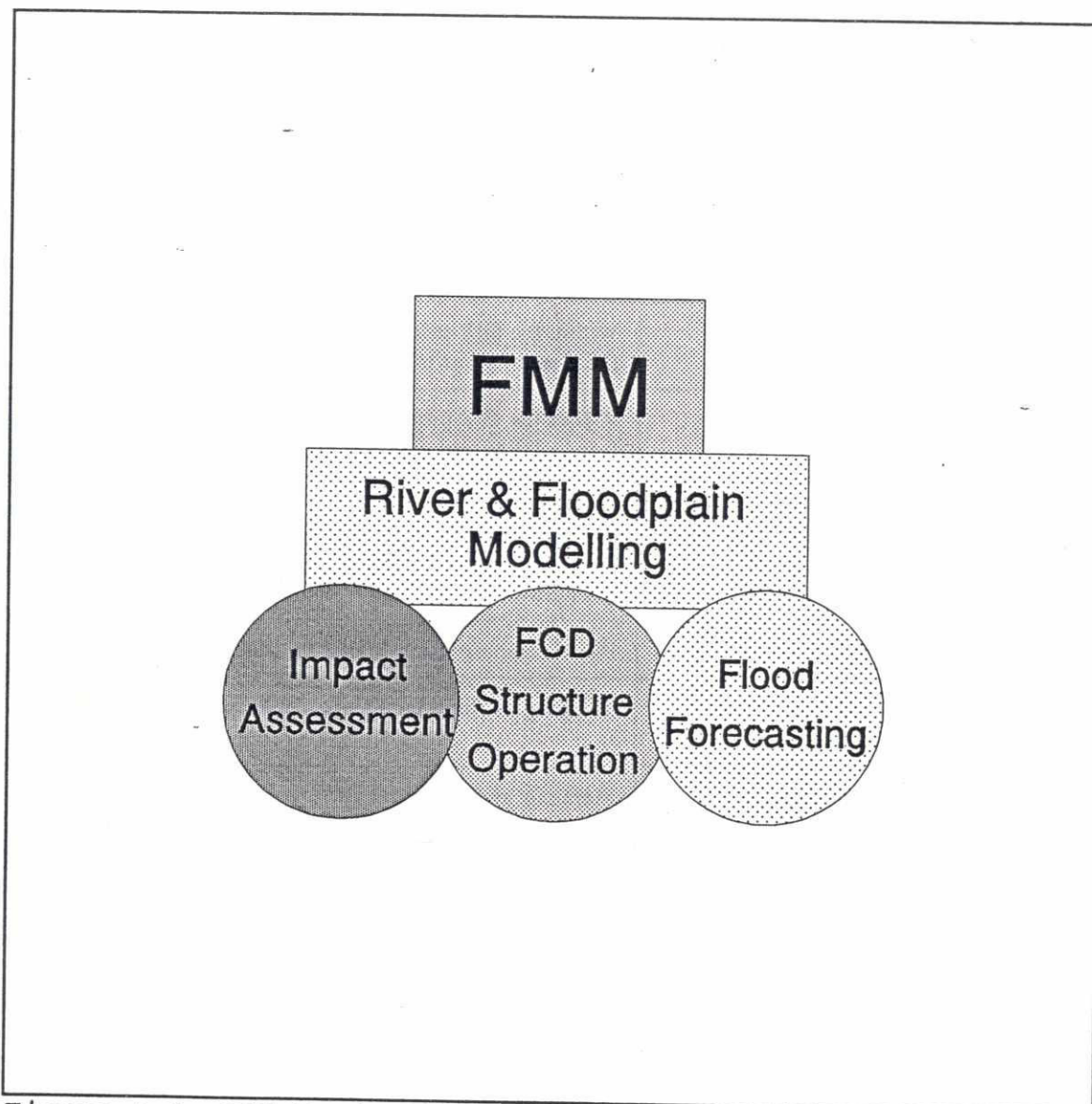


Figure 2.1 FMM Design Themes

Table 2.3 presents a proposed list of the main FMM features grouped into categories. Further details of the features to be developed are presented in Chapter 3 and Section 5.6.2.

Table 2.3 Basic FMM Features

FMM Feature	Description
Enhanced data input to MIKE 11	
Floodplain Cross-Section Profiles	Within the GIS extract floodplain cross-section profiles from a DEM and export in a format readable by MIKE 11.
Flooded Area vs Elevation Curves	Within the GIS produce flooded area versus elevation curves from a DEM and export in a format readable by MIKE 11.
Presentation of MIKE 11 output	
Water Level & Ground Profiles	Display of water level and ground profiles along any line over the DEM.
Flood Mapping	Flood mapping using MIKE 11 water levels and a DEM.
Flood Depth/Phase Mapping	Mapping of flood inundation depths and flood phases.
Flood Duration Mapping	Mapping of flood duration.
Flood Impact Assessments	
Flood Damage Mapping	<p>Flood damage (and benefits) to crops, fisheries and may be infrastructure would be quantified based on simple relationships between flood data (depths, durations) and agriculture/fisheries data (crop type, fish breeding/production potential).</p> <p>The flood damages would be mapped (contoured) and also presented as an overall flood damage cost.</p>
Flood Impact Mapping	<p>The impact of developments on flood levels will be mapped by comparison of results between two MIKE 11 simulations representing the before and after scenarios. The increases and decreases in flood levels would be contoured.</p> <p>The impact of schemes on flood damages (see above) would also be mapped.</p>
Structure Operations	
Upgraded Structure Routines	MIKE 11 structure routines would be upgraded to cover FCD structures typically used at a compartment level.

FMM Feature	Description
On-site structure operations	A new input/output interface for MIKE 11 would be written for use by on-site-FCD structure operators. It will be designed such that no in-depth of knowledge of MIKE 11 is needed.
Flood Forecasting	
Inundation forecast	Logic & methodology will be developed to forecast inundation on a real-time basis in cooperation with BWDB (FF&WC) —
User Interface	
Simple and Robust User Interface	The user interface for the FMM will be simple and robust and will be designed for different levels and needs of users (engineers, planners, scientists, GIS operators).
Documentation	The functions and user interface will be clearly documented using simple and practical examples as illustrations. Training material will be prepared.

upto what extent possible?

2.6 Digital Elevation Models (DEM)

2.6.1 Data Structures for Elevation

A Digital Elevation Model (DEM) is a 3-dimensional (x-y-z) representation of terrain elevations. Typically a DEM is defined as a grid which uses a representation of elevations at evenly spaced locations. Another data structure, called a Triangular Irregular Network (TIN), is able to precisely represent unevenly spaced elevations but is more restricted in the types of analysis it supports. Because elevation data is not usually collected on a grid - or if it is, not on the same grid spacing - some type of processing is needed to create a DEM from elevation data. DEM creation almost always involves some degree of data smoothing. The challenge for the modeller is to create a DEM that works best for the needs of his application, in this case flood modelling.

2.6.2 DEMs for FMM

The purpose of the DEMs in FAP25 is not to model elevation per se, but to represent elevation more accurately to represent the topography of floodplains. This has particular relevance to how embankments and khals are incorporated into the DEM. If the grid cell resolution is fifty meters, then narrow embankments and khals would likely get "smoothed over" if no special steps are taken. Since the influence of these features on the flow of water is great, the cells that embankments and khals pass through will be processed differently. An embankment cell will be assigned the elevation of the embankment - even when the embankment comprises only a small percentage of the cell's area.

TINs provide an important intermediate data structure for representing topography. Their

drawback is that they are not as easy to use in analysis applications. Therefore TINs will be used as intermediate data representation prior to being converted to a grid. It should be noted that TIN functionality is not available on low cost PC based GIS packages, such as Idrisi; however, Idrisi can manipulate DEMs created by FAP25.

2.6.3 GPS Elevations

The elevations used in the DEMs will be with respect to the geoid. It is anticipated that GPS (Geopositional Satellite) receivers will become useful in measuring elevation, at a cost much lower than traditional survey methods. The elevations measured by the GPS receivers, however, are with respect to the ellipsoid - not the geoid. In order to use elevations measured by GPS receivers it is necessary to have a map describing the geoid "height", which is said to vary significantly in Bangladesh. There has been a proposal to the Dept. of Energy to map geoid height (National Mapping Proposal). FAP25 will review such data if it becomes available.

2.7 Application

The Flood Management Model as a new tool will, in general, be applicable to various stages of flood modelling and management, e.g. river and floodplain modelling, impact assessment structure operation, and forecasting. The specific advantages are envisaged to be in modelling flood plains, enhanced input and output facilities. As a decision support tool the FMM will also be useful in water resources planning and development and other FAP studies.

During the present study, the FMM will be applied for demonstrating its use as a decision support tool for the planning, operation and management of flood control and drainage systems on a compartment level as well as on a regional level and on the national level. The Tangail Compartmentalization Pilot Project (CPP) is chosen for the application of FMM at compartment level. The regional FMM will be applied to the North Central Region. The national level FMM will be a coarse model based on the General Model of Bangladesh applicable to assessing the impacts and interactions of major flood control options (e.g., embankments) and various regional plans. Also linked to the BWDB's Flood Forecasting and Warning Centre the GM FMM will be applicable to inundation forecasting at a coarse level. However, the GM will be used to provide boundary conditions to the regional FMM for real-time forecasting of floodplain inundation in the North Central Region. Details of the proposed applications are presented in Chapter 4.

2.8 FMM Accuracy

The FMM is essentially a data analysis and display utility. The accuracy of the FMM is therefore solely a function of the accuracy of the input data.

If a DEM has inaccuracies of up to 0.5m then the flood depths will be incorrect by up to 0.5m.

If the MIKE 11 model in an area is a crude representation of the interaction between the river and floodplain then the flood depths and durations on the floodplain may be highly inaccurate. If rainfall directly onto the floodplain is not represented as inflow to the MIKE 11 model then the FMM can not produce any information on the effect of this rainfall.

It is therefore stressed that the FMM will be a tool for analysing and displaying existing data sets and can only be as accurate as the accuracy of these data sets.

If we still raise questions on the quality of the data and the consultant is unable to say definitely about the quality and is sole dependent on MIKE-11 outputs from SWSC, then FMM study should be stopped immediately.

3. DEVELOPMENT OF FMM

3.1 Methodology

3.1.1 General

Development of the FMM will follow the work schedule detailed in Section 5.6.2. Nine separate tasks (Tasks 210 to 290) are proposed.

The first stage of development (Task 210) will specify the approach for software design and development, and commence coordination of resources, developments and documentation.

The next stages represent the actual software development and represent the four main components of the FMM. The development stages and their associated tasks are presented in Table 3.1. The inter-relationships of the development stages are illustrated in Figure 3.1.

Table 3.1 FMM Development Stages

Stage	Task(s)
System Design and Resource Management	210
River and Floodplain Modelling	220 (MIKE 11 / NAM) 230 (River Network) 240 (Topographic Data) 250 (Flood Surfaces) 260 (Analysis & Display)
Impact Assessment	270
FCD Structures Operation	280
Flood Forecasting	290

The work schedule breaks the FMM development into a series of sub-tasks which will be broken into five actions (Table 3.2). Each sub-task will be the responsibility of two professional resources: a designer who takes overall responsibility, formulates design specifications, carries out validation tests and writes the final documentation, and a programmer who develops and tests the software and documents the work.

The FMM will be developed as a group of software application tools within the MIKE 11 and ARC/INFO environments. Some software external to these environments may also be needed for testing and prototyping purposes.

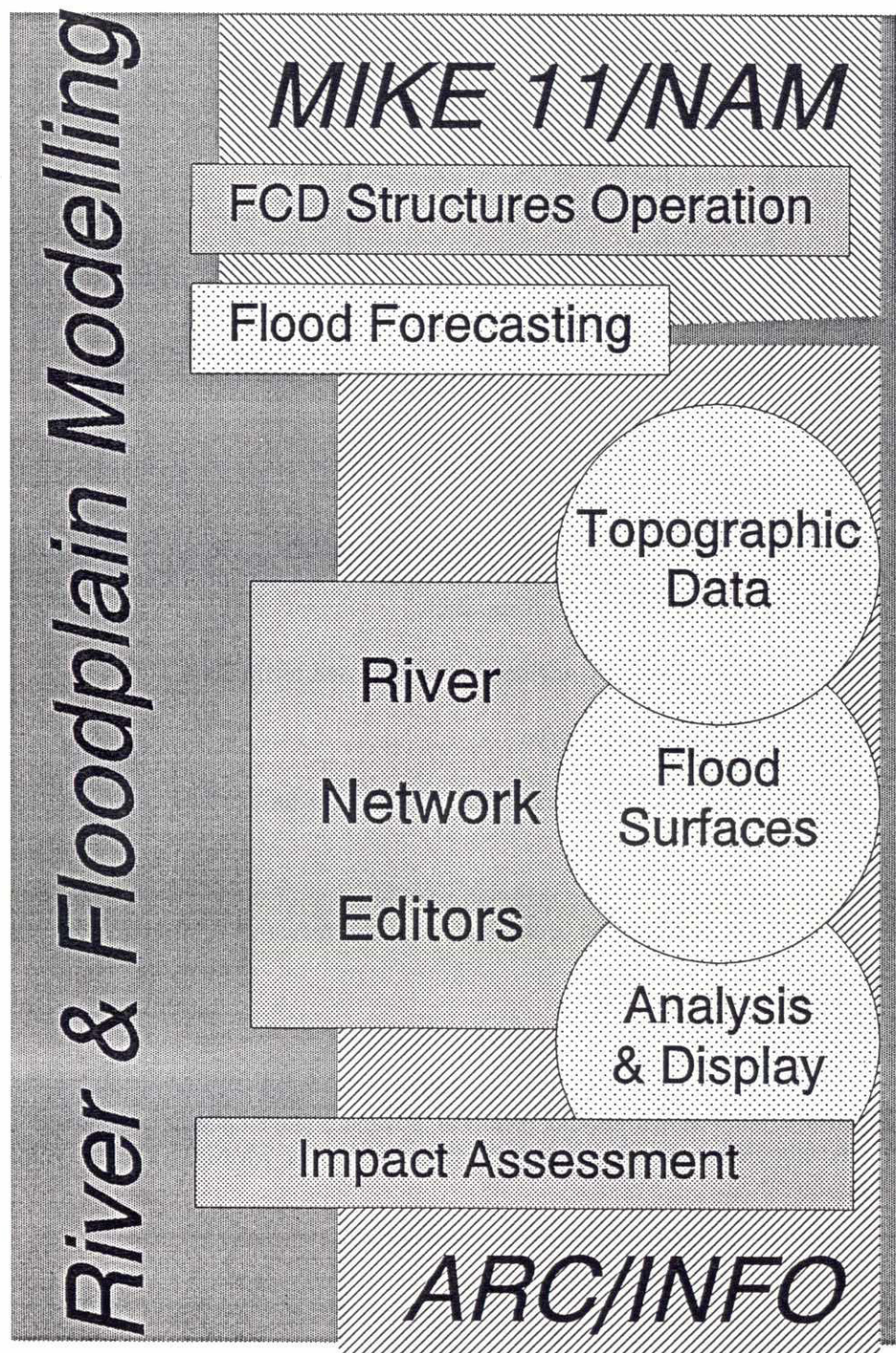


Figure 3.1 Inter-relationships of FMM Development Tasks

Table 3.2 Software Development Sub-task Actions

No	Action	Resource
1	Design and draw up specification.	Designer
2	Develop software.	Programmer
3	Test software.	Programmer
4	Validate software.	Designer
5	Documentation..	Programmer/Designer

3.1.2 User Interface

The FMM will be one overall ARC/INFO application program with a menu driven user interface (excluding the additional features developed in MIKE 11). The advantages to packaging the FMM in this form are:

1. Ease of use by engineers, planners and technicians.
2. Short learning curve.
3. The FMM is immediately available to be used by or transferred to other FAP projects.

Recommendations will be made on porting some of the key FMM developments to a low-cost GIS system because of the high acquisition cost of ARC/INFO.

3.1.3 Documentation

Documentation of User's Guides, worked examples and technical notes will be made to ensure the knowledge and technical advances developed is passed on to future FMM developments and for further application of the FMM within the Flood Action Plan programme.

3.2 River and Floodplain Modelling

3.2.1 Description

Enhanced river and floodplain modelling functions will be developed to facilitate faster and more accurate development of MIKE 11 models and utilise GIS display functions for presentation of output from the models.

River modelling has been divided into five separate areas of development:

1. MIKE 11 / NAM (Task 220)
2. River Network (Task 230)
3. Topographic Data (Task 240)
4. Flood Surfaces (Task 250)
5. Analysis and Display (Task 260)

3.2.2 MIKE 11 / NAM

The MIKE 11 / NAM represents general developments within MIKE 11 and NAM which are necessary to improve the modelling of floods in Bangladesh. Only one development, the interfacing of MIKE 11 and NAM to model the effect of inundation on catchment runoff, is proposed.

The effect of rainfall is taken care in flood modelling by incorporating the NAM simulated catchment runoff into the hydrodynamic model as far as flood prediction in the river channel is concerned. The rainfall-runoff model, NAM is part of the Mike 11 modelling system.

For simulating floodplain flooding the effect of rainfall needs to be considered in a different way than is being done at present by the Mike 11 model. At present, the NAM model is run first to simulate runoff from a catchment for a given rainfall time series. The runoff is then input to the hydrodynamic model as lateral inflow to specified reaches or to points in the river channel. NAM being a lumped conceptual model, simulates the aggregate runoff from a catchment.

One of the main objectives of FMM is to simulate floodplain flooding more accurately. Also, from a flood management point of view it is desirable to simulate the flooding due to local rainfall separately from that due to spills from river channels. This needs a major restructuring of the modelling approach, for example, using flood cells in a quasi 2-dimensional approach. Also, the NAM and hydrodynamic components should be run in parallel so that at every computational step there is an interaction between the two modules. Water exchange between a flood cell and a river channel depends upon both the river stage as well as water level in the flood plain (and also on subsurface water level).

This conclusions / @ observations are to be checked with SWMC

3.2.3 River Network

A river network is a MIKE 11 model network of cross-sections and branches shown in plan view with connections to other data elements such as FCD structures, storage cells, NAM catchments and rain gauges.

Using the river network the FMM user will be able to extract topographic data, create flood surfaces and control the display of flood information within a graphics environment. The river network will be the core for the majority of FMM activities.

River network development is divided into two areas:

1. Development of graphical editors in ARC/INFO's editing environment, ARCEDIT, for digitising river network, FCD structures, storage cells and rain gauge locations.
2. Creation of a water surface GRID (regular mesh representing a 3-D surface) template from a river network. The water surface GRID is a direct function of the river network so it must be created as part of the river network environment. It will use as input the river cross-section lines shown in plan view and/or the storage cells. The resulting GRID is a template from which 3-D water level surfaces will be generated (see Flood Surfaces below).

3.2.4 Topographic Data

Topographic data facilities will facilitate the link between the DEM and MIKE 11's topographic database. It will extract data from the DEM as instructed by the user and transfer this data in formats accessible by MIKE 11.

Specific Features will be:

1. Extraction of cross-section profiles over the floodplain.
2. Calculation of area-elevation curves.
3. Calculation of NAM catchment areas and curves for estimating catchment flooded area.
4. Importing and displaying MIKE 11 river cross-sections.
5. Embankment survey capture into the DEM.

The river network will be used to locate cross-section profiles and delineate polygons for the area-elevation curves.

3.2.5 Flood Surfaces

Flood surfaces will use the water surface GRID template created from the river network to generate 3-D water surfaces and intersect these surfaces with the DEM to produce flood depth surfaces. Generation of flood duration surfaces will also be made by relating flood depth over time over the flood depth surface.

A data management system will be developed to manage the creation of these surfaces when a large number of scenarios are being investigated.

The features will be:

1. Importing of MIKE 11 results data (particularly flood levels) and boundary data.
2. Generation of 3-D water surfaces.
3. Intersection of water surfaces with the DEM to give flood depth surfaces.
4. Calculation of flood duration surfaces.
5. System management of surfaces.

Flood surfaces will be created using the GRID facility in ARC/INFO.

3.2.6 Analysis and Display

Analysis and display is the last step in the FMM river modelling process. ARC/INFO's analysis and display functions will be used to present 1-D, 2-D and 3-D views of time-series, flood profiles and flood surfaces. From these presentations the river engineer will be able to quickly interpret MIKE 11 results and make presentations to the lay-person.

Particular emphasis will be placed on displaying flood inundation extents, flood depth contours and flood durations in 2-D and 3-D views. List of partly and fully inundated areas with location identifications will also be produced for easy reference.

The features will be:

1. Presentations of time-series and profile plots.
2. 2-D and 3-D viewing of flood surfaces, flood inundation, flood depths and flood durations.
3. Overlaying of other coverages such as the river network, roads, infrastructure, agriculture zones, fishery zones, etc.

Statistical analysis functions will also be developed.

Output formats will be developed for different devices: monitor; plotter and printers. The ARCPLOT graphics analysis and display environment of ARC/INFO will be used for the development.

The analysis and display environment will also form the basis for planning and design facilities as described next.

3.3 Impact Assessment

Impact assessment will investigate and incorporate methods for making impact assessments from which recommendations can be made by the planner/engineer. The development of these methods will largely be illustrative within the scope of this first FMM development project. Guidelines and methodology can be used by specific studies.

Impact assessment is represented in the work schedule as Task 270.

The features will be:

1. System for managing the different data types: floods, agriculture, fisheries, infrastructure, etc.
2. Flood level impact mapping of changes in flood levels from proposed works.
3. Flood damage mapping for agriculture and fisheries from changes in flood levels.

Impact assessment functions will reside under the Analysis and Display environment (see above) and will be developed within the ARCPLOT analysis and display environment of ARC/INFO. The ARC/INFO GRID functions will also be used. The river network and flood surfaces created under river modelling will form the main input along with data on agriculture and fisheries.

3.4 FCD Structures Operation

FCD structures operation development will:

1. Improve MIKE 11's representation of FCD structures, using the Tangail Compartment's structures as guidance. **The ability to model a composite of structures as one single structure and the breaching of embankments will be developed.**
2. Prototype a special facility in MIKE 11 designed specifically for: operating structures on-line during a MIKE 11 simulation; training of structure operation staff and for use on-site during day to day operations. It will be able to take input of field data to take into account structure failures, maintenance operations and changes to the normal operation strategy. The features will be:
 - (i) A simple user interface for changing the operation status of structures prior to or during a simulation.
 - (ii) On-line display of selected water levels, discharges and structure openings during a simulation.
3. Investigate the use of structure operation optimisation logic for use on FCD structures.

3.5 Flood Forecasting

FMM is expected to be used in inundation forecasting in conjunction with the forecasting version of the Mike11 models. Flood forecasting component of the FMM will be a document on the recommended logic and procedures for utilising the FMM features described in the previous section on river and floodplain modelling.

During the general model application stage methods will be examined for on-line linkages to flood forecasting activities carried out by FAP10 subject to the next stage of FAP10 commencing late 1993.

- J. would like to know:
- what level of output will be received from other studies?
 - ~~is~~ it the duty of the FMM is only compilation of data?

4. APPLICATION OF THE FMM

4.1 Introduction

The application of the FMM technology includes development of a system of bespoke models on various scales (national, regional and compartment scales). These will be based on the General Model, (GM), North Central Regional Model (NCRM) and the Tangail Compartmental Model (TCM). The system of models will be operated at different levels - central, regional and compartmental and applied to different purposes, such as:

off-line flood management, i.e. training, planning and design purposes;

on-line flood management, i.e. real-time flood forecasting and management.

Table 4.1 summarises the model basis, the level of operation, the main drainage features which may be accommodated at the various model scales and finally, main application areas. The bespoke FMM developments will be carried out in stages, the first stage involving a coarse model to test the concepts and logic for demonstration and training and identifying additional data collection and the second stage developing full integration with the DEM and the GIS.

As clearly indicated in the TOR (Appendix A), the present study aims at demonstrating the use of FMM and will develop a concrete framework for achieving the long-term objectives. Hence, the applications will be carried out on a pilot scale at different levels. The following outputs are envisaged:

- **National Level:** A coarse FMM using the existing General Model for off line prediction of flood plain inundation for various scenarios of river floods, rainfall and embankment and structure configurations. Linked to BWDB-FFWC's (FAP 10) flood forecasting model, it may be used for inundation forecasting (but at coarse level).
- **Regional Level:** A detailed pilot FMM for the North Central Region using the verified NCRM of SWMC (eventually allowing for some additional details in selected areas) for prediction of flood plain inundations as for the General Model above. However, as described in Section 4.3, the difference would be in detail; extent and depths of inundation would be less coarse, **ideally giving more accurate forecasts at Upazila level;** and simulating different configurations and operational models for compartments and polders.
- **Compartment Level:** A detailed FMM at compartment level using the existing model for Tangail Compartmentalization Pilot Project (CPP) developed by FAP 20 for predicting inundation depths and durations for various management strategies, but with greater accuracy. It would test out the effects of operation of hydraulic structures and, as a pilot for a more comprehensive management model, would introduce flood impact assessment on agriculture, fisheries etc by coupling with GIS. Detailed descriptions of the development of the application models are provided in the following sections and the workplans for the corresponding

How the Polders were selected? What are their boundaries?

activities and task are laid out in Chapter 5.

Table 4.1 Flood Management Model - Basic Characteristics and Applications

		FMM Basis	
Characteristic Applications	General Model	Regional/sub-regional model	Compartmental Model
Possible Model Operation Level	Central level	Central or Regional level	Central, Regional or District Level
Potential Model Users	BWDB, WARPO, RRI, DoE, BIWTA, BUET, consultants	BWDB, WARPO, RRI, DoE, RHD, MoA, BIWTA, BUET, consultants	BWDB, FPCO, LGEB, MoA, Project Committees, BUET, consultants, NGO's
Typical Drainage Features in the Model	*Major river drainage network	*Regional river drainage network *Compartments as controlled hydrological units *Subcompartments (1,000-2,500 ha) as uncontrolled hydrological units	*Compartment with major drainage network *Subcompartments (1,000-2,500 ha) as controlled hydrological units *Subcompartment units (100-250ha) as uncontrolled hydrological units
Main Types of Model Application	Off-line: Development of flood management strategies. Planning, design, training and demonstration. On-line: Real-time flood forecasting and management.	Off-line: As for GM On-line: Real-time flood forecasting and management, but only on central level	Off-line: As for the GM On-line: Flood management, structure operation.

What is the involvement of data collection for other similar areas

4.2 General Model

4.2.1 General Model of SWMC

The General Model of Bangladesh has been developed at SWMC mainly for the study of macrolevel planning issues. The GM is also used to generate boundary conditions for the regional models. A special version of GM (GM-FF) has been used for real time flood forecasting by FAP 10 at the Flood Forecasting and Warning Center of BWDB. Another version of GM has been used by the FHS component of FAP 25 to carry out longterm historical simulations.

SWMC updates the GM on a regular basis and verifies it with the latest available hydrological data. The last update and verification was done in July 1992 (Ref. 2). A major update is being done at present and it is expected that this final update will be finalised by April 1993. FAP 25 have obtained the recent version of GM from SWMC. However, it is expected that the model will be updated by April 93. The basic GM of SWMC and other versions are briefly described below.

River System

The three major rivers, i.e. the Jamuna, Ganges-Padma and Meghna, with their major tributaries and distributaries (Table 4.2) make up the hydrodynamic component of the GM. The scheme plan of GM is presented in Figure 4.1

Table 4.2 River Systems in the General Model.

MAJOR RIVER	MAIN TRIBUTARIES	MAIN DISTRIBUTARIES
Jamuna	Dharla Teesta Atrai	Old-Brahmaputra Dhaleswari
Ganges	none	Gorai- Rupsa- Madhumati system
Padma	none	Arial Khan- Biskhali system
Upper Meghna	Surma-Kushiyara- Kangsa-Boulai- Kalni system Old-Brahmaputra Dhaleswari	none
Lower Meghna	none	Tentulia-Lohalia system

Flood Plains

Flood plains are represented in the General Model in many different ways. In the original set up (Ref. 3), the flood plain boundary of the GM was delineated from the 1 in 20 year

return period flood depth map by the National Water Plan of MPO (now WARPO). This boundary data and spot level data from the square kilometre grid were used to generate an area-elevation function. This area elevation function is transformed into a width-elevation function by dividing the representative channel length (the portion contained within the flood plain). The width elevation function is then combined with the cross sections of the rivers using a higher relative roughness on the flood plains to represent vegetation and other obstacles on the flood plain.

A quasi 2-dimensional approach is adopted to model the flood plain flow in the left bank of Jamuna by schematizing a series of spill channels and cross-connections (Figure 4.1). During the recent update, flood plain definitions have been revised in the rivers falling in the North Central and North Eastern Rivers.

What is that revised definition?

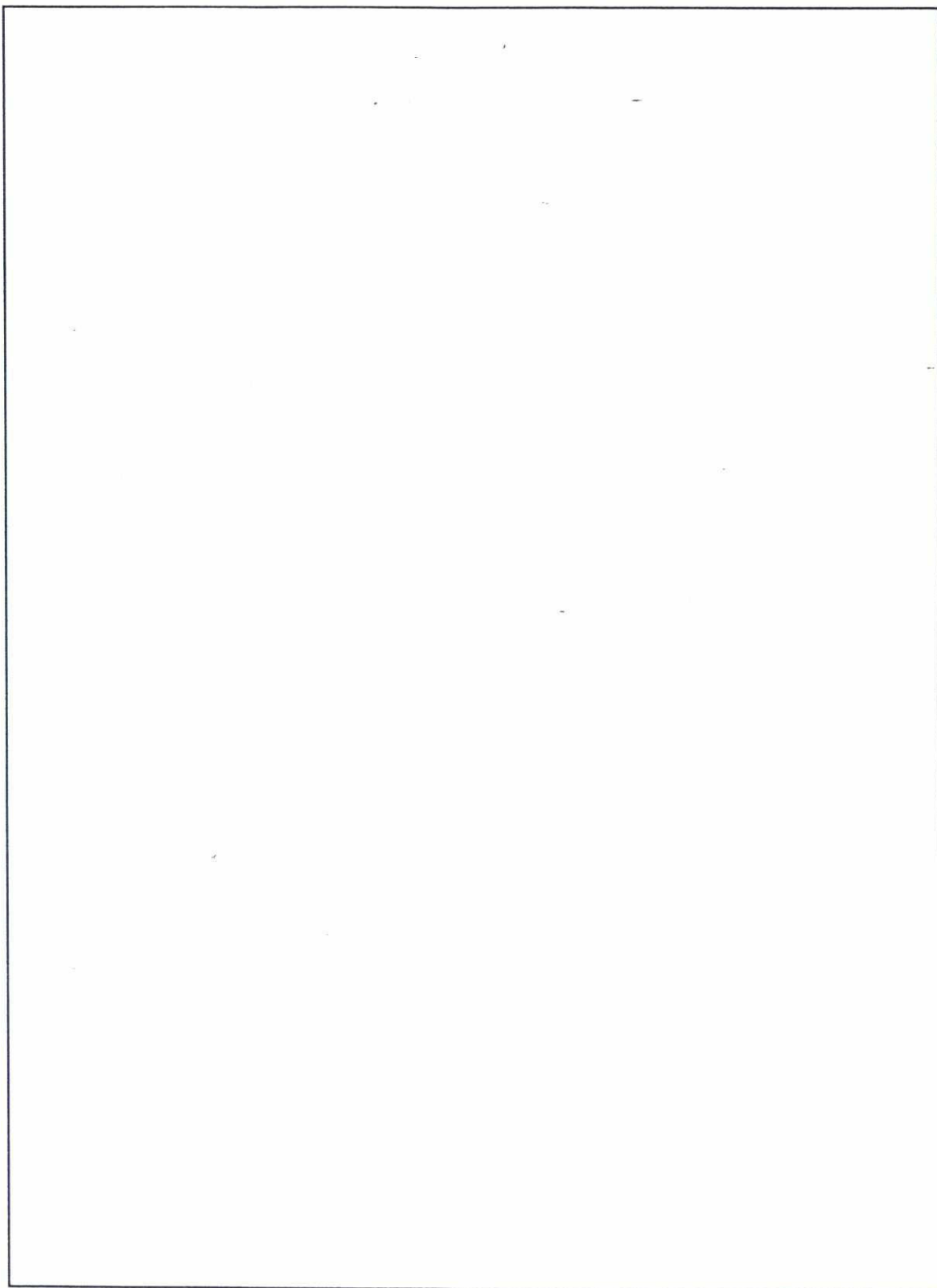
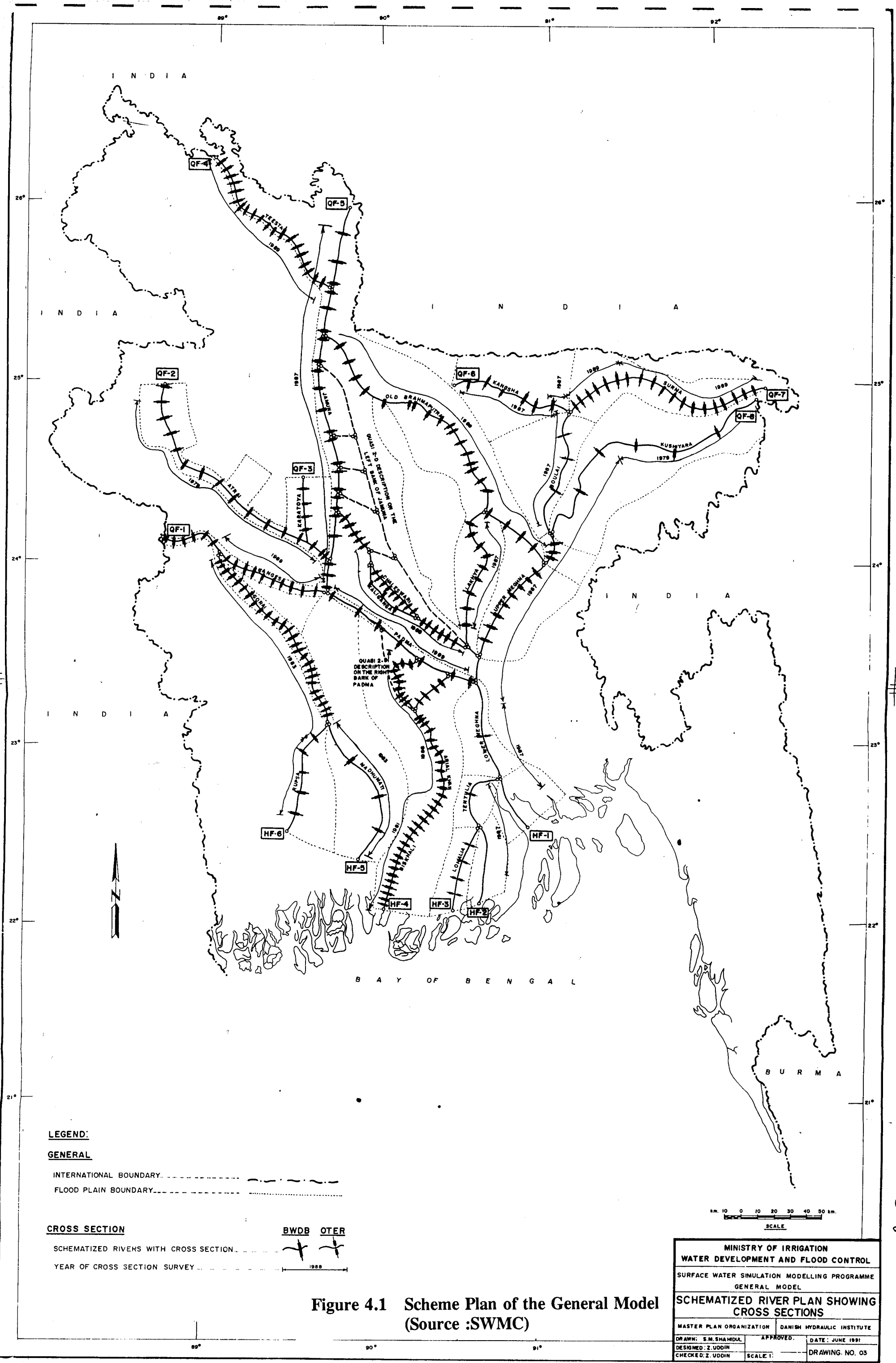


Figure 4.1 Scheme Plan of General Model
(Source: SWMC)



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Cross-Sections

Table 4.3 shows the number of river cross-sections used in the General Model, together with their source (surveyed by) and the year.

Table 4.3 River Cross-sections used in the Updated General Model.

River	Length in km	No. of X-sections	Surveyed Year	Surveyed by
Jamuna	210	31	1986-87	BWDB
Ganges	119	18	1990-91	BWDB
Padma	104	15	1988-89	BWDB
Lower Meghna	85	9	1990-91	BWDB,MRBPS
Upper Meghna	125	20	1989-90	BWDB
Dhaleswari	148	29	1988-89	BWDB, JBA
Old Brahmaputra	241	38	1991-92	BWDB, SWMC
Lakhya	115	20	1989-90	BWDB
Kaliganga	62	10	1986-87	BWDB
Gorai	197	32	1988-89	BWDB
Upper A. Khan	36	12	1987-88	BWDB
Surma	172	29	1990-91	BWDB
Kushiyara	132	9	1991-92	SWMC
Kalni	72	17	1991-92	SWMC
Bhogakangsha	40	5	1991-92	SWMC
Someswari	17	3	1991-92	SWMC
Nawa	28	3	1991-92	SWMC
Baulai	114	14	1991-92	SWMC
Ghorausra	34	5	1991-92	SWMC
Ghulamkhal	26	3	1991-92	^XxMC
Atrai	150	16	1978-79	BWDB
Bishkhali	96	17	1980-81	BWDB
Tentulia	70	3	1986-87	BWDB
Lohalia	60	6	1986-87	BWDB

River	Length in km	No. of X-sections	Surveyed Year	Surveyed by
Karatoya	20	5	1978-89	BWDB
Makar	8	3	1988-89	JBA
Madhumati	128	17	1991-92	SWMC
Rupsa	85	11	1991-92	SWMC

NAM Connection

The rainfall runoff model (NAM) computes the runoff to the rivers due to rainfall. For this purpose the whole area covered by the GM has been divided into several NAM catchments.

Rivers which pass through each catchment are defined and also the total catchment area. The runoff is transformed into discharge and distributed along the river reaches. The catchment delineation and parameters of the NAM model are based on the calibrated regional NAM models. As the GM covers only selected regional rivers, the regional NAM catchments are lumped. As a result, 48 catchments (including 7 river catchments covering the surface area of the three major rivers) are now incorporated in the GM. The NAM Catchments are shown in Figure 4.2

Boundary Conditions

There are 8 upstream discharge boundaries in the General Model as shown in drawing GM-2. These are at Pankha (Ganges - discharge at Hardinge Bridge applied with a time lag), Mahadevpur (Atrai), Ullapara (Karatoya), Dalia-Doani (Teesta), Noonkhawa (Jamuna - discharge at Bahadurabad with a time lag), Jariajanjail (Kangsa), Kanairghat (Surma) and Sheola (Kushiyara).

There are 6 downstream water level boundaries as shown in Figure 4.1. These are at Daulatkhan (Lower Meghna), Dasmonia (Tentulia), Galachipa (Lohalia), Patharghatta (Bishkhali), Rayenda (Madhumati) and Chalna (Rupsa). The mean daily water levels computed from low and high tide levels are used as model boundaries.

Model Performance

The General Model performance has been found satisfactory as far as the main rivers are concerned (see Ref.2). It is expected to improve the performance in the secondary rivers during the ongoing updating. The performance assessment at SWMC is based on comparison of the simulated flows and water levels with the observed data in the related river channels. Due to lack of observed data and the structure of the model, performance in the flood plain and smaller khals cannot be assessed. Also, recent findings of the FINNMAP topography survey (FAP 18) indicate benchmark differences between the right and left bank gauges along the Jamuna river. This will necessitate a recalibration of GM by SWMC.

Mr. A. Hakim
is to discuss
on the latest
B.M. Station

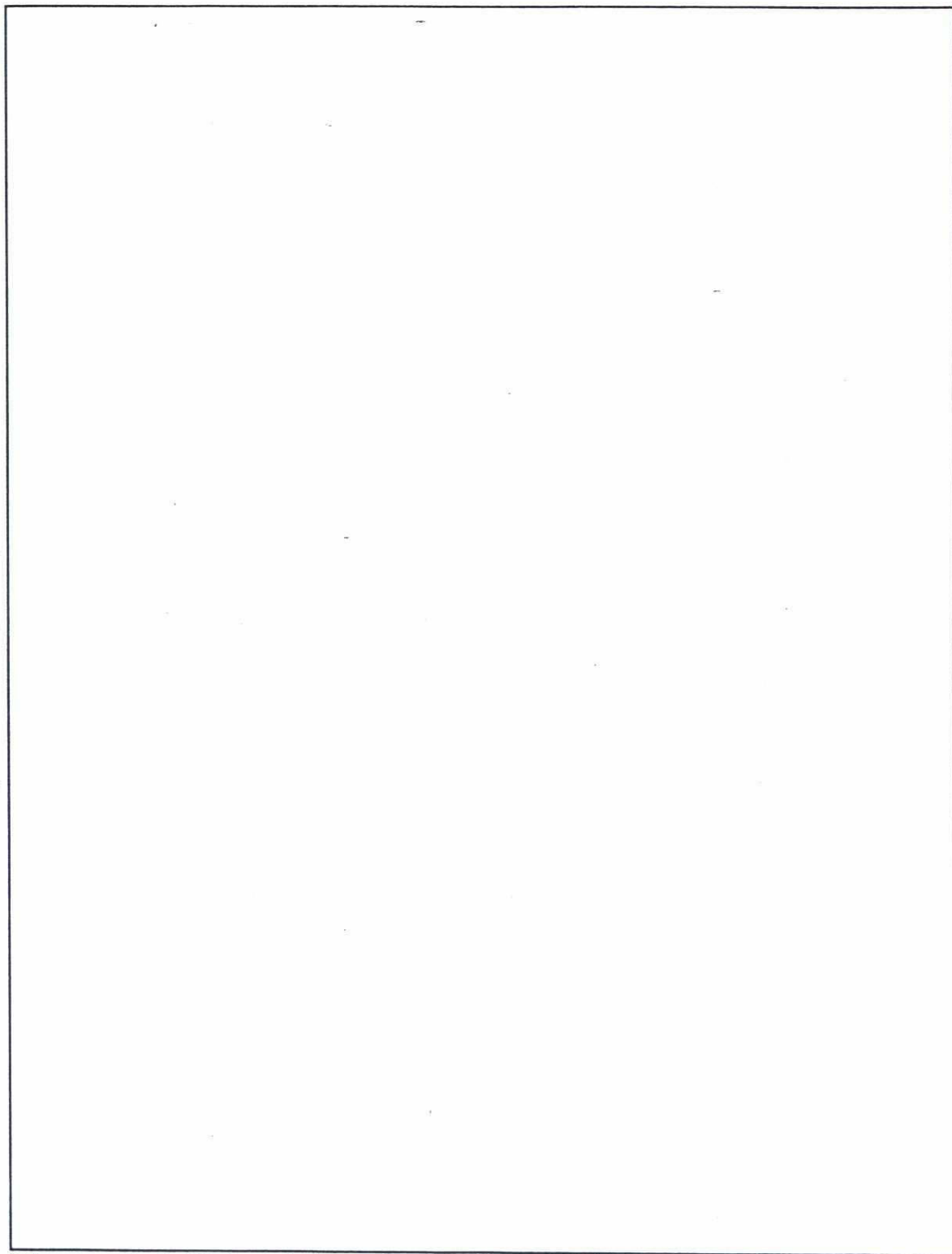
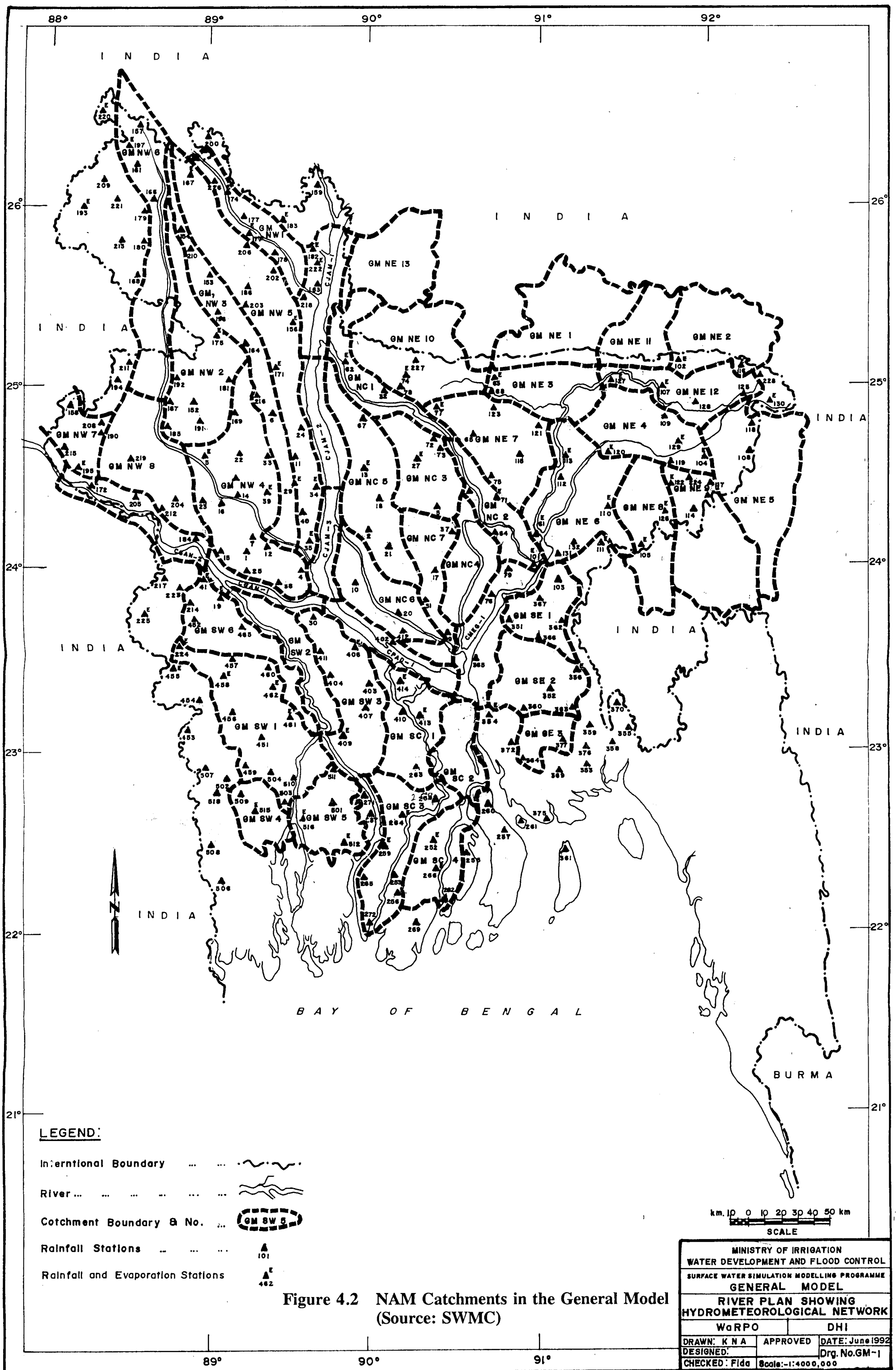


Figure 4.2 NAM Catchments in the General Models



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4.2.2 GM-FAP 25

GM-FAP25 is a dedicated version of the GM developed by SWMC. The model is used for long term Simulation (1965-89) for the purpose of establishing hydrological basis for engineering design criteria and to assess the effects of alternative flood protection scenarios on water levels and flow distribution along the major rivers. The model schematisation is shown in Figure 4.3

The main difference between the GM-FAP 25 and the GM are the following;

- The Ganges schematization is extended up to the Indian border at Pankha, using cross sections available in the flood forecasting version of the GM (GM-FF).
- The Teesta river is not included in the model, because a shorter time step would have been necessary for the computation of the flood in this flashy river. Instead, its discharge is introduced at Kaunia as a lateral inflow in to the Jamuna.
- Low (artificial) base flows have been introduced in the old Brahmaputra during the dry season, to avoid mathematical instabilities. These flows have been chosen low enough not to affect the results of the model.
- The Karatoya river is not included in the GM-FAP25.

Pre-determined
affairs?

Boundary Condition

The GM-FAP25 used the boundary condition similar to GM except that the station Ullapara on Karatoya river is not included.

why?

NAM Model

A total of 26 rainfall stations have been used as inputs for the NAM model, 3 stations for each region plus 11 additional stations in the North East region to better represent the high rainfall gradient in that region.

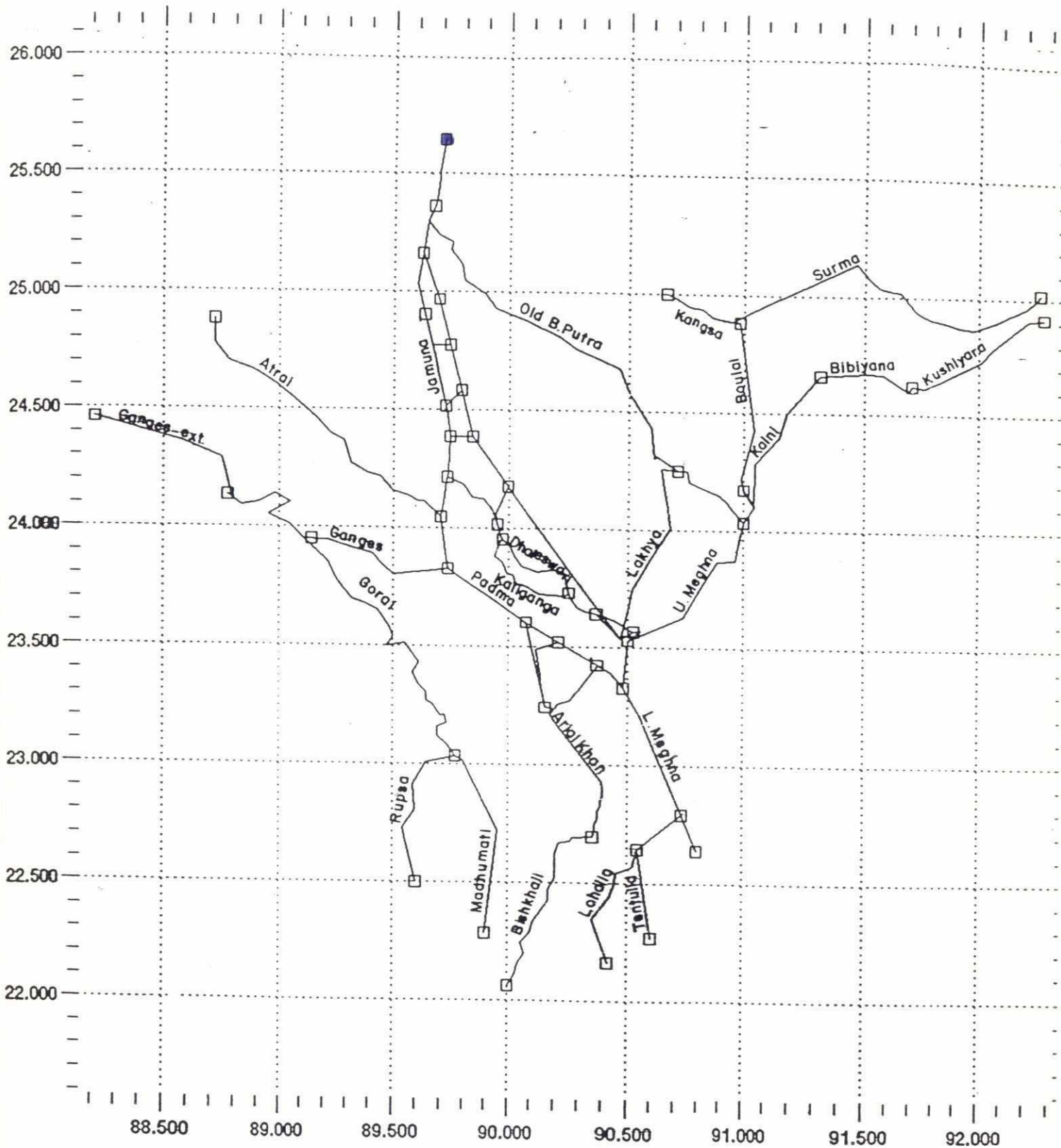


Figure 4.3 Schematic of GM-FAP25

Model Performance

The validation of the model has been based on the comparison of computed and observed water levels at 22 stations along the major river, their tributaries and distributaries. A comprehensive error analysis has been carried out for annual peak, sub-seasonal and seasonal mean values (Ref. 4).

The standard deviation of errors are similar in the entire model area. For peak water levels it is typically 20-30 cm and for daily water levels 15-30 cm. The overall model errors are less than 0.2m in about 45% of the time and less than 0.4m in about 75% of the time.

Revised hydrological basis for establishing engineering design criteria would be available as and when the updated SWMC GM becomes available. Before undertaking the 25 years simulation (Run 7, Task 350) an assessment of actual improvements in GM performance will be made.

4.2.3 GM-FF

GM-FF is the modified version of the General Model used for real time flood forecasting during the last monsoon. In GM-FF some rivers have been extended up to the Indian border, while the downstream part of GM in the South West Region is not included in the flood forecasting setup. In yet another version GMX the main rivers are extended inside India to receive real time data from Indian Stations. The main rivers and their upstream boundaries in the model are as follows:

Upstream boundary

River	GM-FF	GMX
Ganges	Pankha (Border)	Farakka
Jamuna	Noonkhawa	Dhubri
Kushiyara	Amalshid	-
Surma	Kanairghat	-

Other important rivers are maintained as in the GM.

Figure 4.4 shows the schematic of the GM-FF. Modifications are also made in the rainfall runoff component (NAM). There are 29 NAM catchments, in each of which the weighted mean areal rainfall is calculated on the basis of the real time FF&WC network. (See

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Ref. 5).

The General Model utilizes water levels from 28 real time stations partly as the boundary to the model and partly as forecast and updating points, (Table 4.4). The model setup includes boundaries from 13 locations. For 12 of these locations real time water level data are available and with the water levels as input, the model automatically transfers the level to discharge on the basis of the cross sections included in the model. For Arial Khan, at Madaripur, which is a downstream boundary, a Q-H relationship (rating curve) is specified.

Table 4.4 Real Time Rainfall Stations

STATION	AREA
Kurigram	North West
Kaunia	"
Rangpur	"
Bogra	"
Panchagarh	"
Dinajpur	"
Rajshahi	"
Pabna	"
Dalia	"
Chilmari	"
Serajganj	"
Naogaon	"
Dewanganj	North Central
Jamalpur	"
Mymensingh	"
Tangail	"
Dhaka	"
Kushtia	South West
Jesoore	"
Faridpur	"
Sylhet	North East
Sunamganj	"
Sheola	"
Moulvi Bazar	"
Habiganj	"
Durgapur	"
Kanairghat	"
Manu Rly Br.	"
Bhairab Bazar	"
Comilla	South East
Chandpur	"

Forecasts are issued at 16 localities, (Table 4.5, Figure 4.4). The two stations, Dhaka and Taraghat, are also included in the more detailed North Central model, which also includes forecast points at 4 other locations.

MIKE11-FF

General model
(1991 setup)

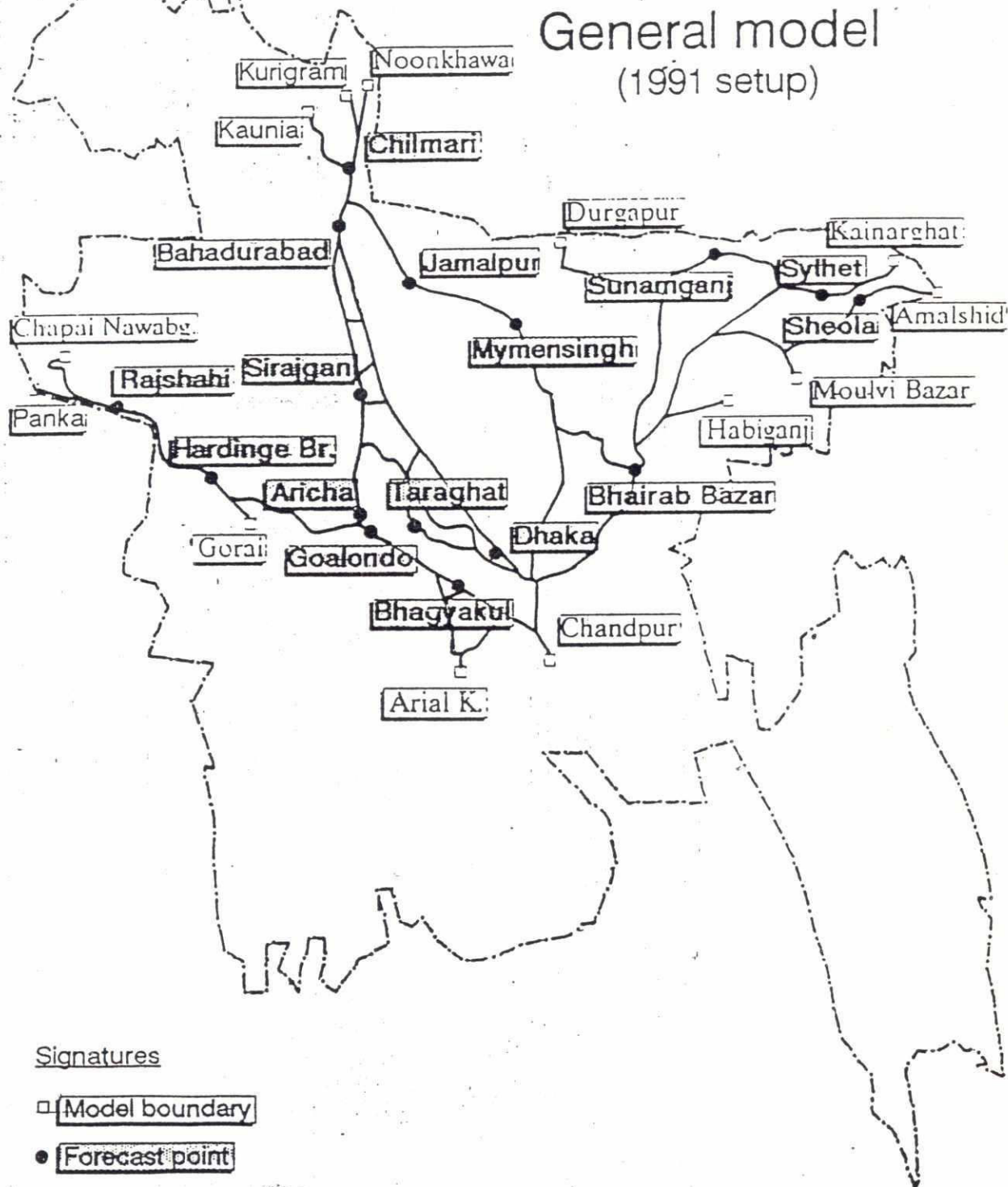


Figure 4.4 Schematic of GM used in Flood Forecasting

Table 4.5 Water level stations, model boundaries and Forecast/updating points.

STATION	RIVER	TYPE
Kurigram	Dharla	Upper Model Boundary
Kaunia	Teesta	"
Noonkhawa	Jamuna	"
Chilmari	Jamuna	Forecast and Update
Bahadurabad	Jamuna	"
Serajganj	Jamuna	"
Aricha	Jamuna	Forecast and update
Jamalpur	Old B.Putra	Forecast and Update
Mymensingh	Old B.Putra	"
C-Nawahgonj	Mahananda	Upper Model Boundary
Panka	Ganges	"
Rajshahi	Ganges	Forecast and Update
Hardinge Br	Ganges	"
Goalondo	Padma	"
Bhagyaikul	Padma	"
Gorai Rly Br	Gorai	Lower Model Boundary
Kanaighat	Surma	Upper Model Boundary
Sylhet	Surma	Forecast and Update
Sunamganj	Surma	"
Amalshid	Kushiyara	Upper Model Boundary
Sheola	Kushiyara	"
Moulvi Bazr	Manu River	Upper Model Boundary
Habiganj	Khowai	"
Durgapur		"
Bhairab Baz	Upper Meghna	Forecast and update
Chandpur	Lower Meghna	Lower Model Boundary
Dhaka	Buriganga	Forecast and Update
Taraghat	Kaliganga	Forecast and Update

4.2.4 DEM for GM

A coarse DEM of Bangladesh covering the entire country except the Sundarbans and some area of the Chittagong Hill Tracts has been developed by FAP 19 (Ref. 6). This is based on the MPO 1 km grid elevations. This will be used by FAP 25 for a coarse national level flood mapping, i.e. for planning and flood forecasting applications. The planning applications will allow modellers to edit the DEM to reflect proposed embankments. The location and height of the embankments will be determined by the modeller. The application will not determine optimal embankment locations, but will allow comparison between proposed embankments.

Note that the 1 km grid is very "smooth"; bumps, such as villages, comprise only a small

percentage of total area, hence their elevation has not been retained. Flood extent maps created solely from the GM DEM, therefore, may show inundation where there is none and none where there is. Other sources will be reviewed to provide a means of determining impacts of inundations predicted by DEM. For example, the MPO has tabulated land inundation type (F0...F3) for each upazila. By comparing the area-elevation curve predicted by the DEM for a particular upazila with its tabular breakdown of inundation type, it may be possible to define risk levels for the upazila. Methods for doing this will be explored.

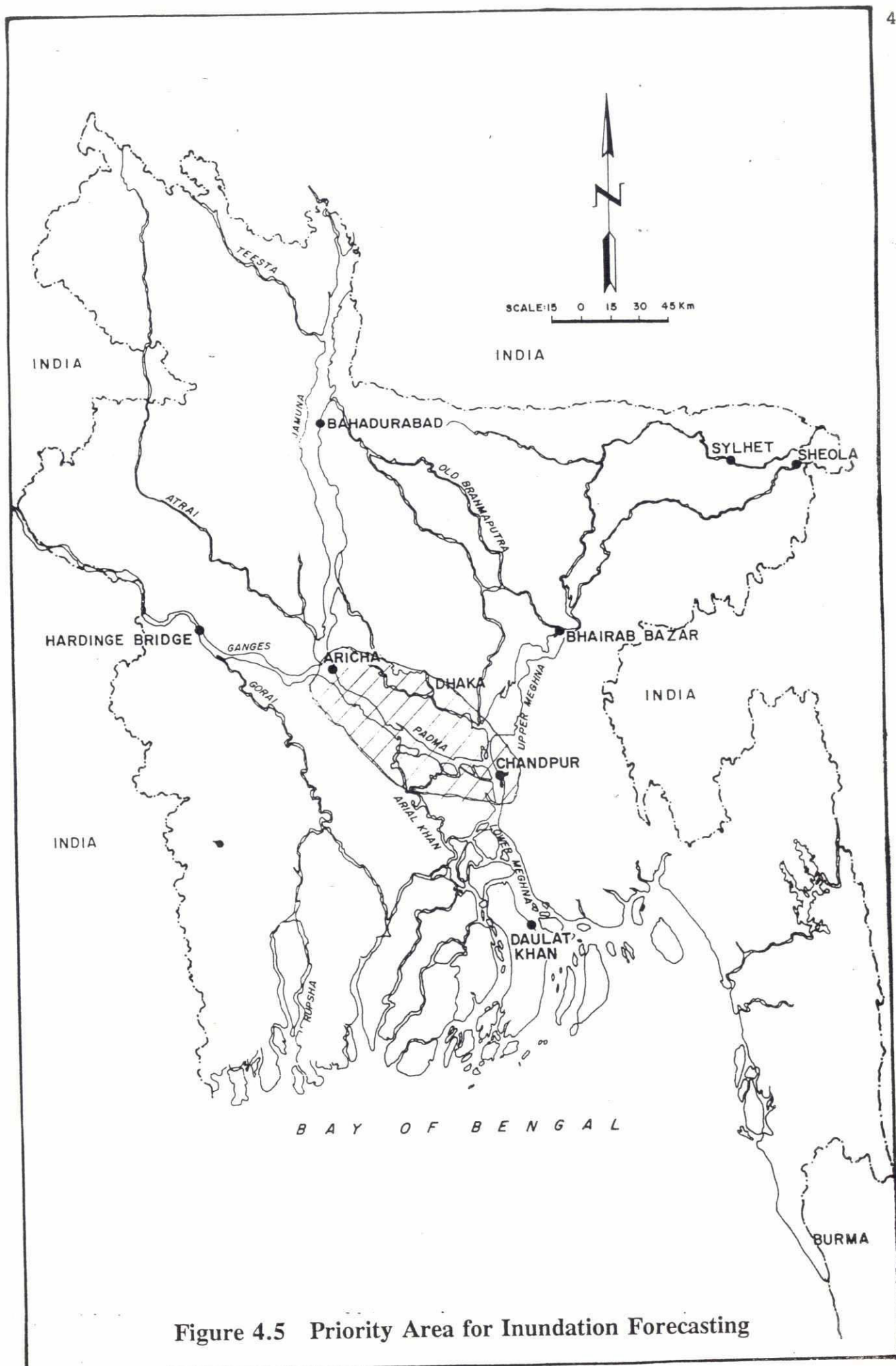
It may be useful to digitize village locations, along with their elevations, as points. The village elevations could be incorporated into the GM DEM, and could also provide a description of population distribution as it relates to elevation. Methods for doing this will be explored, possibly in collaboration with FAP19.

4.2.5 Concept and Methodology

The basic purpose of the national FMM is to assist in general flood control planning and management (including real time flood forecasting) in Bangladesh. Specifically, the tool will be used for:

- (i) off-line prediction of flood plain inundation for various hydrological scenarios as well as large scale structural flood control (embankments) scenarios; and
- (ii) linked with the forecasting model of BWDB (FF&WC) for inundation forecasting at coarse level.

Thus, in addition to adopting the GM developed at SWMC, the two other versions described above. GM-FAP 25 and GM-FF - will be used. The central focus of this application is "flood mapping" both for off-line as well as on-line information. However, owing to the coarse resolution of the GM and its inability to represent flood plain to the details required for inundation forecasting and the coarseness of the national DEM (1 Km grid) the model output will be coarse and should be used as "indicative" only. Attempts are being made to improve the quality of "flood mapping" in selected areas. Figure 4.5 shows the priority areas selected for this purpose. The areas are in and around Greater Dhaka, right bank flood plain of Jamuna and along the Ganges-Padma river.



The basic approach of "flood mapping" for both the off line and on-line (forecasting) applications is to superimpose the MIKE 11 generated water surface with the improved DEM. Using the flood maps, off-line relationships between river water levels and flood plain inundations will be developed for various scenarios based on pre-run simulations. These relations can then be used for long term flood management as well as in real time inundation forecasting.

The DEM used by FAP19, a refinement of the MPO 1km grid, will be used by FAP25 for planning and forecasting applications. Tools will be developed so that modellers can perform the following tasks.

Planning

- edit the DEM to reflect proposed embankments
- create a new MIKE 11 setup file based on topography in DEM.
- run MIKE 11 simulations using new setup files.
- create flood extent maps using modified DEM and water levels predicted by MIKE 11.

Flood Forecasting

- edit the DEM to more accurately reflect existing topography.
- create new MIKE 11 setup file based on topography in DEM.
- run MIKE 11 simulations using new setup file and hypothesized or historic flood events.
- create summary statistics of simulations for flood forecasting gauge stations.
- Archive the simulations in a form that can be easily restored.
- Using existing (i.e. real-time) water levels, find archived simulations that closely match.

Note that matching archived simulations in the flood forecasting application is primarily a pattern recognition problem. Neural Networks have shown much promise in pattern recognition. Application of neural networks will be explored.

4.3 North Central Regional Model

4.3.1 Introduction

During the course of the Flood Action Plan Regional Studies, it was recognised that the modelling tool available upon which planning level decisions were to be based was barely adequate for such purposes. Indeed, for some particular flooding situations, the results generated by the existing regional models could be misleading, if incorrectly interpreted. A more refined and specific tool was required to address the deficiencies at regional, sub-regional levels, and, to a lesser extent, national level.

This specific regional modelling tool, (FMM), should ultimately provide significantly more information on the flooding characteristics and extents of the flood plains. This is not the specific purpose of the regional models being developed in the Surface Water Modelling Centre. The emphasis of such models is to accurately simulate the water levels and discharges in the river network, treating the flood plains as "black boxes", contributing to the total storage and conveyance in a lumped manner only, (except in certain isolated locations). SWMC Regional models could be used, however, to specify boundary conditions for sub-regional models within the river network.

4.3.2 Project Objectives

The overall objective of the Flood Management Model is to develop and demonstrate prototypical models at the General, Regional and Sub-Regional levels. The concepts of linking the MIKE 11 outputs with Digital Elevation Models, (DEM's), will be developed such that more comprehensive information of flooding characteristics on the floodplains can be presented.

Additional components, more specifically related to Geographical Information Systems, (GIS), will be linked to these outputs to show the potential for enhanced information output and analysis.

The FMM for the North Central Region will be tailored to provide specific information on flood extent, flood duration and depth of flooding resulting from a limited number of agreed scenarios comprising embankments and compartments.

It is important to appreciate the prototypical nature of the models to be developed within the framework of this study. Present limitations of data accuracy and the time available for comprehensive additional data collection preclude the production of totally, up-to-date, representative models, capable of presenting a definitive statement on the absolute nature of flood characteristics at a regional level. The existing DEM is based on the 1957-63 4" and 8" to the mile BWDB contour maps, which are known to be unrepresentative in some specific areas and may possibly be so in the majority of the coverage. The development of the FMM tool at this time without up-to-date topographic information remains, however, a fundamentally sound concept, since the future development of a fully representative FMM then becomes only a function of the accuracy of the data inputs, the basic conceptual "engine" having already been constructed.

4.3.3 *Relevance to other studies within the North Central Region*

The anticipated outputs from the North Central Regional FMM will be tailored to user requirements. These requirements have been determined from interviews which are detailed in Table 2.1.

A large proportion of the end-users of the FMM are associated with the Flood Action Plan studies and therefore the resultant outputs will reflect this. FAP-3, the North Central Regional Study, (Reference 7), was executed during the period April 1991 to May 1992. The accuracy of the analyses in this study were limited owing to the coarse nature of the model employed. **The Coarse Pilot Model developed during the study, (with refinements from the Surface Water Modelling Centre), was not capable of quantifying the flooding characteristics of all the flood plains in a realistic way.**

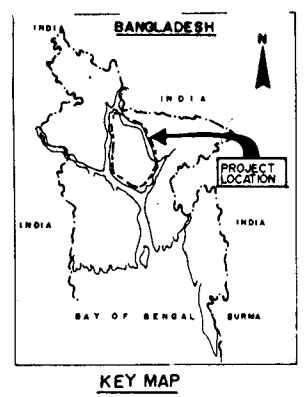
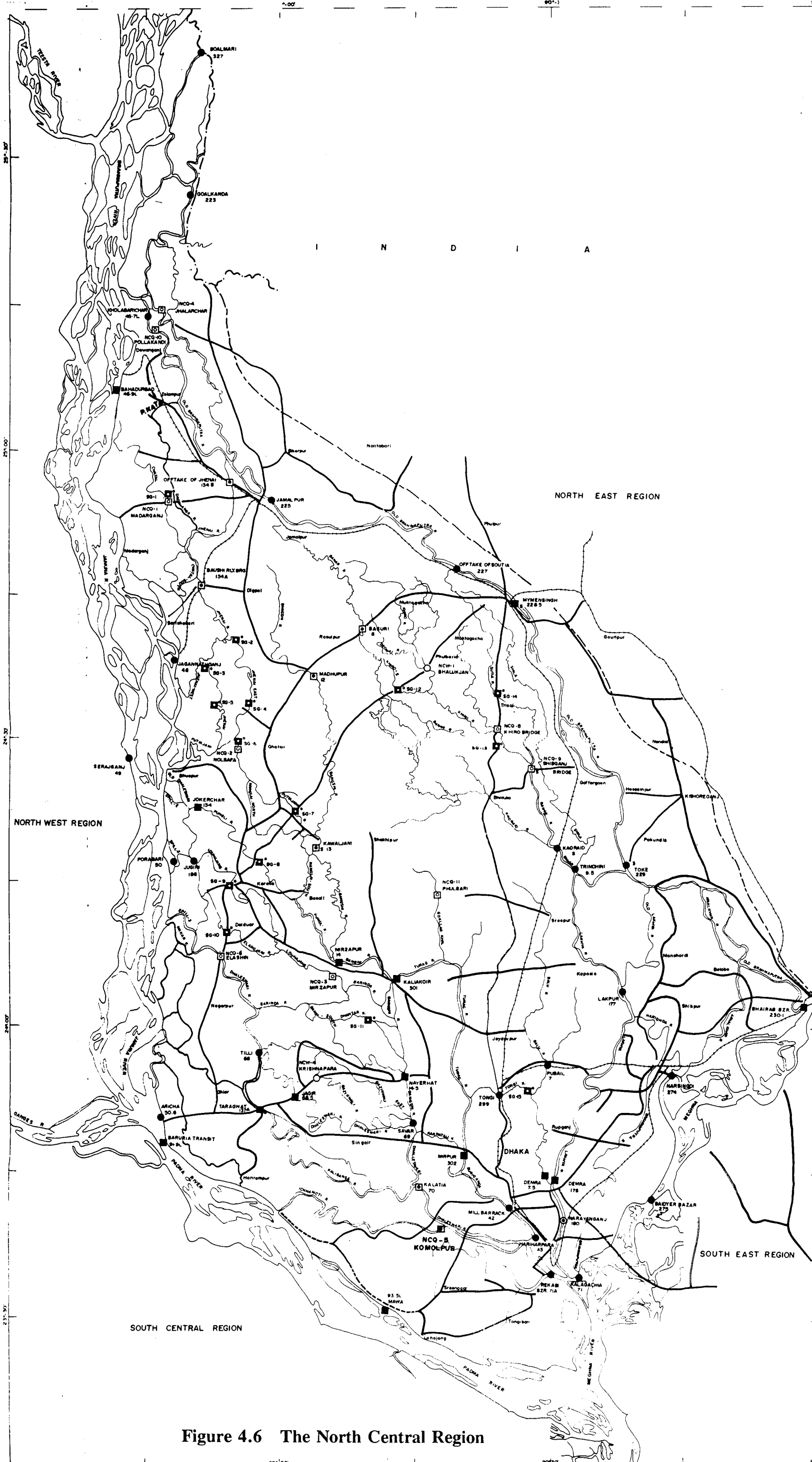
The limitations of one-dimensional modelling for the analysis of flood plain flooding of the type found in the North Central Region has been recognised. The FMM for the North Central Region will be based on a quasi 2-dimensional approach to modelling in areas where the configuration of flood plains justify such an approach, and to a level of detail that remains commensurate with the philosophy of regional modelling. Figure 4.6 shows the North Central Region, together with the network of hydrometric stations used in the present modelling environment.

Based on the results of the analyses, (including, but not restricted to the hydraulic model), FAP-3 developed a water development plan for the North Central Region which identified a number of potential projects to be further investigated to feasibility level. Figure 4.7 identifies the proposed projects and their location. Precise detailing of these projects is not appropriate in this report, but they are based on local drainage, (through river improvement), compartmentalisation and controlled flooding and embanking.

The continuance of the feasibility level studies for the above projects will require the development of suitable hydraulic models, constructed with a detail appropriate to such a level of planning. The existing NCRM, even with its recognised limitations, is appropriate for pre-feasibility level studies only. Significant further development will be required. The regional FMM will form a skeletal framework upon which the final feasibility level models may be constructed.

The Jamalpur Priority Project and the Tangail Pilot Project are both studies based on sub-regions of the North Central Region. The specific problems of the Tangail study are addressed in a dedicated component of this study and are discussed in Section 4.4. The Jamalpur Priority Project is presently under feasibility level study, with a more detailed sub-regional MIKE 11-based hydrodynamic model used as a tool for analysis, (Reference 8). **Deficiencies in this computer model lie not in its basic structure, (as in the NCR model), but in the basic data available for calibration.** Very few hydrometric stations lie within the sub-region for comparison points.

Both the regional and sub-regional models lack a suitable module for post-processing of the generated results. That is, given the water levels in the river and flood plain, (to whatever degree of accuracy possible), the translation of this information to areas, depths and



- LEGEND:**
- GENERAL**
- INTERNATIONAL BOUNDARY
 - REGIONAL BOUNDARY
 - RIVER & CHANNEL
 - RAIL WAY LINE
 - ROAD RHO NATIONAL HIGHWAY
 - RHO REGIONAL HIGHWAY
 - RHO FEEDER ROAD TYPE-A
- WATER LEVEL**
- SWMC WATER LEVEL (SHOURLY) STATIONS
 - SWDB WATER LEVEL (SHOURLY) STATIONS
 - OTHER WATER LEVEL (SHOURLY) STATIONS
- DISCHARGE**
- SWDB DISCHARGE (NON-TIDAL) STATIONS
 - SWDB DISCHARGE (TIDAL) STATIONS
 - SWDB WATER LEVEL STATIONS UPGRADED BY SWMC TO DISCHARGE (NON-TIDAL) STATIONS
 - SWDB WATER LEVEL STATIONS UPGRADED BY SWMC TO DISCHARGE (TIDAL) STATIONS
 - SWMC DISCHARGE (NON-TIDAL) STATIONS
 - SWMC DISCHARGE (TIDAL) STATIONS
- SEDIMENT**
- SWMC SUSPENDED SEDIMENT STATION
 - SUPERSCRIPT 'O' STANDS FOR OLD STATION

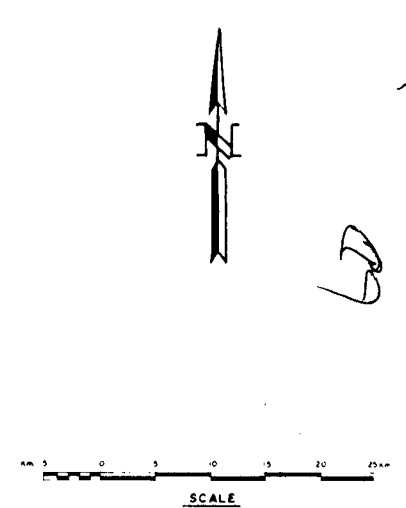


Figure 4.6 The North Central Region

MINISTRY OF IRRIGATION
WATER DEVELOPMENT AND FLOOD CONTROL
SURFACE WATER SIMULATION MODELLING PROGRAMME
PHASE-II

NORTH CENTRAL REGION MODEL AREA

HYDROMETRIC NETWORK

MASTER PLAN ORGANIZATION DANISH HYDRAULIC INSTITUTE

DRAWN S.M. SHARIF/SAH APPROVED DATE: JULY 1992
DESIGNED S. BOUQUI GROUP LEADER, NCRM NCRM-2

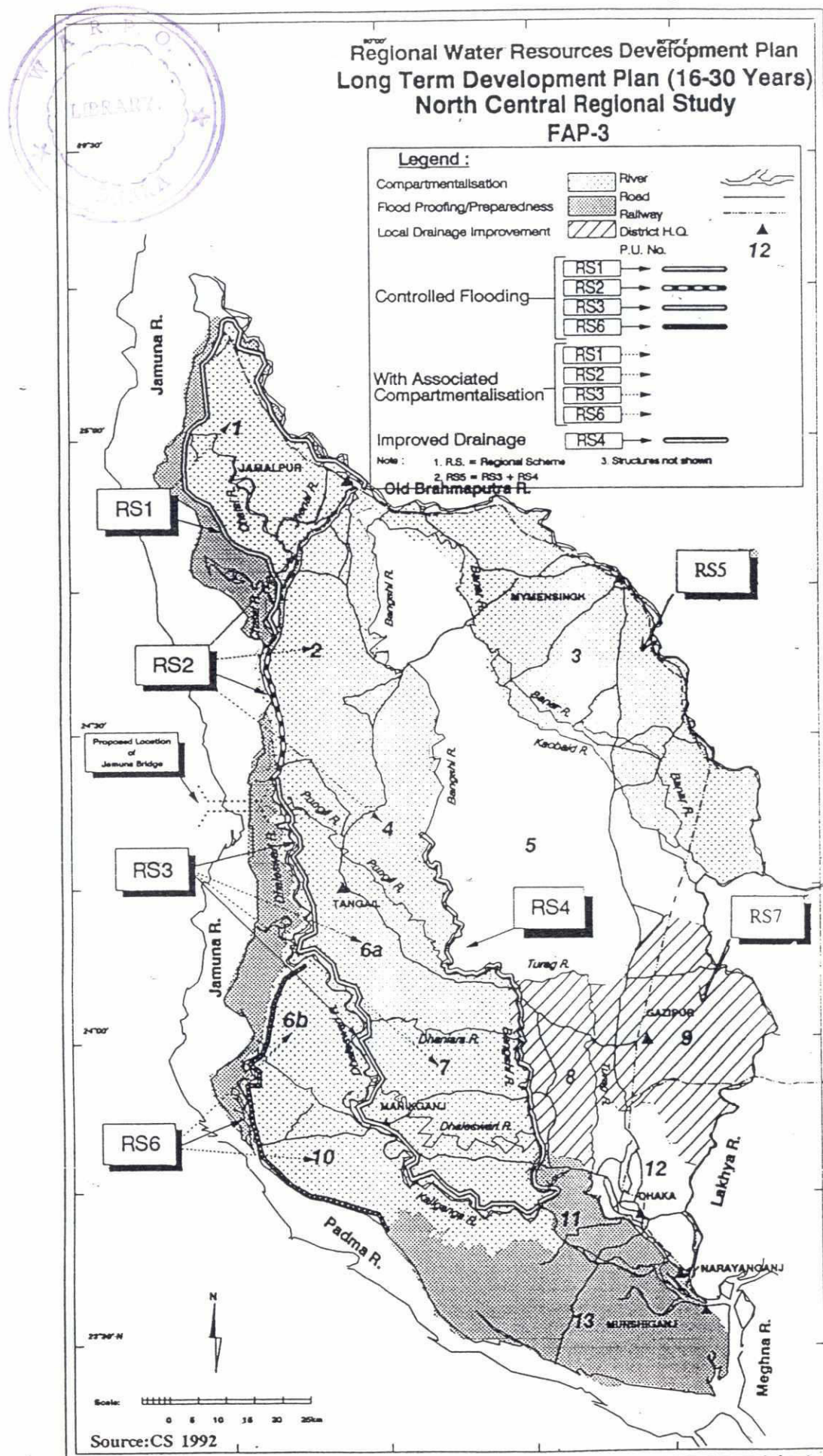


Figure 4.7 Proposed Projects in the NC Region

durations of flooding requires lengthy and cumbersome off-line routines to be developed for each individual requirement. The output from the Regional FMM will provide a means by which such information can be readily obtained through interaction with the GIS.

4.3.4 DEM of the North Central Region

FAP19 has digitized elevations for the western part of the North Central Region using the BWDB 4 inch map series, circa 1960. The DEM for the eastern part will be based on the MPO square km grid. Present day river locations will be used to remove obsolete elevations. Refinements to these DEMs will be based on availability of survey data, with priority given to embankment elevations.

For some river branches, cross-sections will be used to "carve out" a TIN in a path following the river channel. The elevations from these TINs will then be used to update the DEMs.

It is likely that the detail of the model will need refining for villages not shown on the original BWDB maps. Elevations of these villages, as well as embankments, will be sought through existing survey or design data. Field surveys may be conducted for critical embankments, if the budget allows. Information about structures on the embankments, such as bridges and culverts, will be jointly reviewed by the FCD Engineer and the Software Specialist to determine the most appropriate way of representing them in the DEM.

The resulting DEMs will be made available in a format compatible with Idrisi, a low cost PC based GIS.

4.3.5 Data Base

The Regional FMM will utilise the existing data bases for its development. Appendix D1 contains a complete listing of data sets available for use by the Regional FMM study.

4.3.6 Additional Data Collection

The FMM project contains no specific component for survey works other than a financial provision for a limited amount of data collection to be done by others. Resource constraints have dictated the extent of additional topographic survey possible.

Since the NCRM requires considerable restructuring in certain areas so as to realistically represent the flood cell structure, topographic survey should concentrate on establishing the locations of water interchange between river and flood cell. Moreover, the specific lines which should be surveyed must be limited to those watercourses having the most significant influence on the regional hydraulic behaviour.

To this end, a limited programme of survey works is being conducted and is detailed in Appendix D-2. The inclusion of a component for flood cell survey is to assist in the assessment of the accuracy of the existing DEM. This is to provide a reference which will be compared to the existing DEM, both for its use in the hydrodynamic computations and

in the derivation of flooded areas. Further hydrometric surveys will be undertaken during the monsoon period. Attention will be directed towards establishing the extents of flooded areas. This activity is being carried out in a pilot area south west of Dhaka around Manikgunj and Savar (Appendix D-3). A total of 10 water level gauging stations have been identified for observing the water level throughout the monsoon season.

Should further feasibility level studies be undertaken in the region, the additional survey requirement would be significant. It would not be proper to quantify such survey within the framework of this study, since a much more detailed investigation is required, provision for which is not made in this study. However, the level of additional survey works required for FAP 3.1 and FAP 20, (both sub-regional studies), over and above those for the regional model indicate that a major commitment must be made. In addition to some re-survey of regional rivers, together with further bank-line surveys, the intricate network of internal khals must be detailed, since these have a significant impact at sub-regional modelling level.

In addition to further topographic survey, a much higher resolution of hydrometric measurements will be required for feasibility level modelling. The khal system mentioned above, is presently without hydrometric monitoring stations and a completely new network will be needed to be designed, implemented and monitored. The location and extent of such monitoring cannot be defined at this time, and it will not be until the nature and extent of the modelling detail needed is ascertained, that such monitoring networks can be defined.

4.3.7 Concepts of the Regional FMM

The purpose of the Regional FMM is to provide an overview of the hydraulic and agricultural impacts of proposed FCD schemes, at planning and pre-feasibility level, particularly as they relate to the flooding characteristics of a region. Basic information will be the water levels in the river and flood plain network as calculated by the hydrodynamic component of the MIKE 11 software. The network structure should be set up so as to allow for the potential independent response of the flood plains to flooding from rainfall and river channel spills.

There is no concise definition for the level of detail required in a regional FMM. There can be no single FMM for any region, only a basic river and flood plain network in sufficient detail to realistically represent existing conditions for establishment of baseline situations for planning and pre-feasibility studies. If engineering interventions are proposed in the region, or a part thereof, a specific setup of the river and flood plain network must be constructed to reflect these changes, e.g. proposed embankment alignments and elevations must be imposed, proposed major compartments delineated. It is probable that, initially, compartment delineation will be restricted to the minimum required to realistically represent the proposed construction. Indeed, at planning and pre-feasibility level, it is unlikely that further detail would be available or justified.

Given a "without project" base situation in which the flooding characteristics are modelled as accurately as possible, within the constraints of the accuracy of the data sets, the general effects of the engineering proposals within the sub-region can be qualified and, (at an appropriate level), quantified. Of equal importance, the "knock on" effects of such proposals may be seen on a regional scale. This latter factor will serve to define the

required extents of the more detailed sub-regional model in respect of the location of boundary conditions, since it is important to fix all boundaries of the models at points which would remain largely unaffected by the engineering works. Only a regional FMM can do this effectively.

Taking the project development one stage further, the sub-regional model would now be developed. The detailed areas would be of limited geographic extent, concentrating on the physical works only, but the limits of the model would extend beyond the sub-region to the boundary locations identified by the regional FMM. Much more detail would be incorporated into these sub-regional models, with sub-compartments and minor structures included.

It is almost certain that the results from the sub-regional models would differ somewhat from the initial findings of the regional model. In this case, the regional model would be modified appropriately to reproduce the sub-regional model results as closely as possible and within the constraints of detail. Running the regional model again, incorporating these changes, would yield the revised regional implications of the sub-regional development proposals. Thus there should be a hierarchical system of models, with the lower level, (sub-regional), feeding back to the higher level regional model.

It must be emphasised that the regional model should never be considered as being the sum of a number of more detailed sub-regional models. Such a concept would yield a cumbersome and impractical package, far too large and with excessive run times. As sub-regional schemes become implemented, so the baseline regional model should incorporate the necessary modifications to the appropriate level of detail.

4.3.8 Methodology

The restructuring of the NCRM will involve additional calibration in order to achieve satisfactory agreement with the measured water levels and discharges in the river network. The extent of this restructuring is not fully known at the present, but it is probably overly optimistic to expect the entire region to be remodelled fully under this study. The DEM for the eastern sub-model is not yet digitized but this will be undertaken during this project. This sub-region will not be examined in detail, as proposed schemes in the western area have greater priority. The west and east sub-models will, however, be combined for the Regional FMM.

The approach to be followed will be to improve the existing regional model in total to a degree of detail that results in a model capable of demonstrating the overall concepts of the FMM. The purpose of the study is to demonstrate that tools can be developed which enhance both the information available and the presentation of this information, on a regional scale. Therefore, what is developed must be reproducible in other regions of Bangladesh. The emphasis must, therefore, be on the incorporation of different structural options at locations which best demonstrate their effect, rather than concentrating on any specific areas within the NCR. Thus the concept of choosing a single area within the NCR, (or any of the specific FAP-3 selected projects), would not be appropriate.

The choice of the structural options, (or combination thereof), will be based on the outline

of discussion with FPCO and the NCR regional study.

Calibration of the models with respect to flood plain inundation will be difficult, since it is known that the existing DEM may not be fully representative. No attempt will be made to make significant adjustments to the basic DEM. Of principal importance, however, is the establishment of "break lines", (lines of embankments, roads etc.), that are not represented in the existing DEM. The alignment and levels of these features will be the dominant characteristic of the FMM, as too will be the interaction between them and the river system.

Preliminary work in establishing major features will be done using the DEM and aerial photos, (stereoscopic pairs).

In order to evaluate the extent and temporal pattern of flooding, it is proposed to investigate the uses of radar imagery from the ERS-1 satellite. These images are obtained by side looking radar which can penetrate cloud layers and are thus capable of presenting a time series through the monsoon. A time series of processed images through the monsoon will be invaluable to the project in assisting in the calibration of the FMM.

Flood forecasting using the Regional FMM:

It is planned to use the NCR-FMM in real time flood forecasting by FAP 10 (BWDB FF&WC) in cooperation with FAP25. The regional flood forecasting will be done in two stages. First the General Model will forecast water levels which will then be used as boundaries for the regional model. The NCR-FMM will then be used in flood forecasting including inundation forecasting. Inundation maps will then be produced.

4.4 Tangail Compartment Model (TCM)

4.4.1 Schematization

For FAP 20 (Tangail Compartmentalization Pilot Project, CPP) a mathematical model of the Tangail compartment, based on the MIKE 11 software, has been developed which is used as a tool in the planning stage of the project (Ref. 9). This model consists of two modules, the hydrological model NAM and the hydrodynamic model.

The Tangail compartment is divided into 16 sub-compartments including Tangail town. These sub-compartments are again divided in smaller parts finally resulting in a total of 24 rainfall-runoff catchments which assure a proper rainfall-runoff distribution of the compartment. For all the catchments runoff to the various locations of the open channel network has been computed using the hydrological module NAM for the selected periods.

Apart from the sub-compartments, the Lohajang floodplain is also included in the model studies.

The hydrodynamic model comprises 27 channels connected at 39 nodes. The channels were selected depending on the following criteria:

- the importance of the channel in terms of flooding
- the importance of the channel in terms of drainage

The schematization has been designed such that it can represent all situations from low flow to heavy inundation. This is achieved by making the grid follow the major khal system and by including the floodplain section and its associated storage at higher flood levels. The dead storage (beels) in the floodplain is also taken into account.

The model boundaries are selected upon the following factors:

- preferably, discharge boundaries should be applied upstream and water level boundaries downstream
- the boundaries should be selected at locations where hydraulic conditions are not affected by the future project condition.

The upstream boundary of the model is extended up to the Dhaleswari offtake. The downstream boundaries are taken in the Lohajang river at Mirzapur, in the Pungli river at the southern border of the project and in the Dhaleswari river at the junction with the New Dhaleswari river (Figure 4.8, Table 4.6).

All the schematized channels were surveyed from November 1991 onwards and the collected channel cross-sections are used in the model. The relevant cross-sections of Dhaleswari, Elanjani and Pungli rivers have been collected from FAP 3. The floodplain data are collected from the BWDB maps of 8 inch to a mile scale with 1 ft. contour interval from 1964. The maps were used to prepare area-elevation curves for every sub-compartment.

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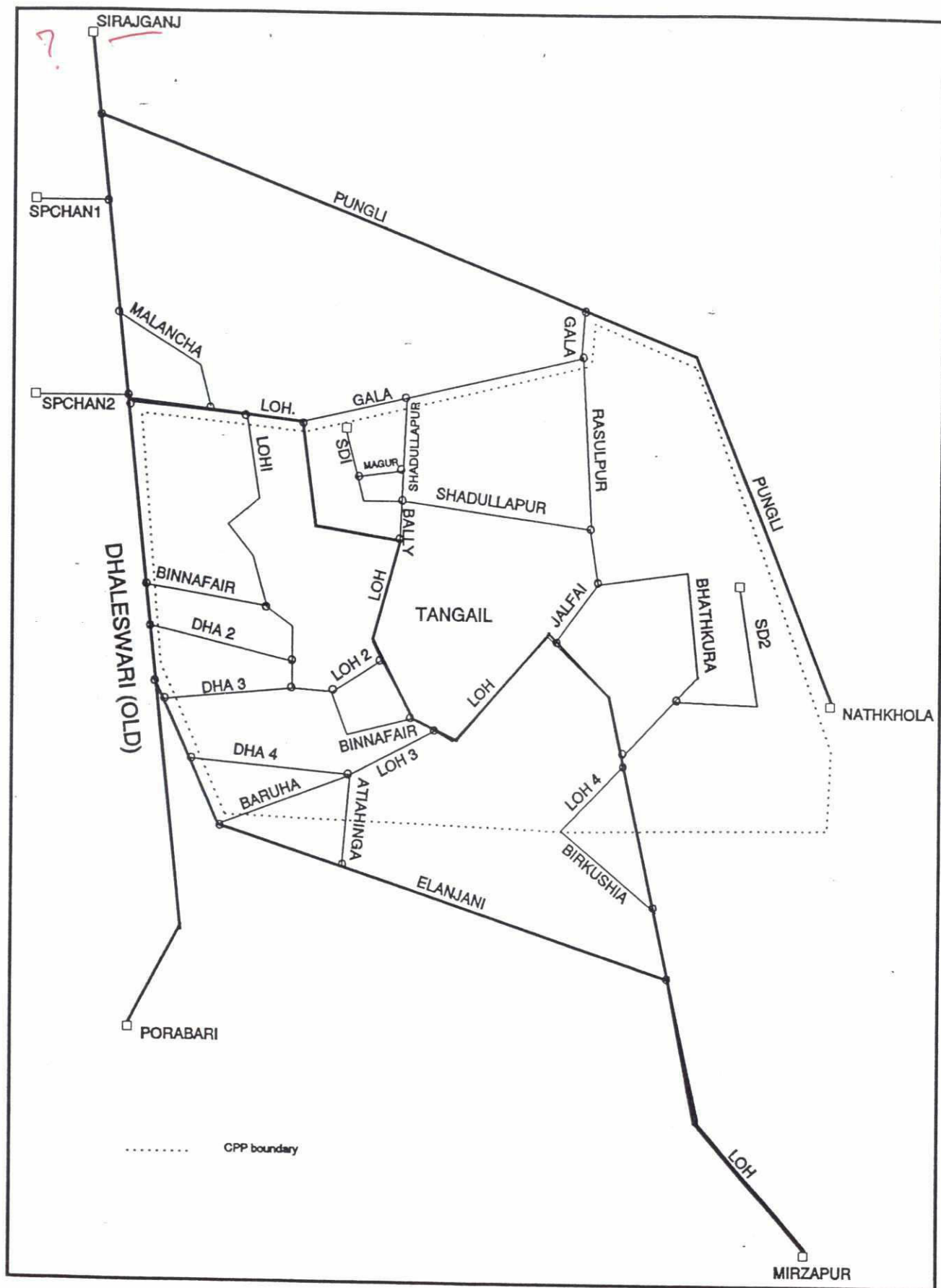


Figure 4. 8 Channel Layout in TCM

Table 4.6 Channels included in the model.

Channel name	Length in Km	Number of X-S
Old Dhaleswari	38.0	9
Pungli	31.5	7
Elangjani	25.0	7
Lohajang (LOH)	53.0	27
Gala Khal	7.0	5
Binnafair	9.25	16
Fatehpur Khal (DHA2)	3.5	6
Indra Belta (DHA3)	2.0	3
Belta Sarai (DHA4)	4.5	6
Baruha	3.31	5
Jugini (LOH1)	6.0	5
Gaziabari (LOH2)	2.4	8
Deoijan (LOH3)	4.0	3
Atia-Hinga	2.5	4
Kumuli (LOH4)	3.0	4
Birkushia	2.0	5
Bhatchanda (SD1)	4.25	4
Magur	2.0	1
Bally	2.0	9
Shadulla	6.9	11
Rasulpur	4.0	5
Jalfai	3.26	8
Bhatkura	5.59	6
Surooj Khal (SD2)	5.0	3
Malancha	3.0	6
Spill Chan1	6.54	3
Spill Chan2	7.2	3

4.4.2 Model Performance

The CPP model is calibrated against the 1991 situation for the period May till November (14 water level measuring stations were installed in the Tangail Compartment in May 1991). The overall calibration shows a good agreement between measured and computed data (Ref. 9). Many scenarios were developed to test the concept of compartmentalization, 10 of them have really been tested with help of the model. The final 'with-' and 'without-project' situations have been simulated for the years 1987, 1989 and 1991. The present model gives enough detail to study the peripheral control for the planning and design phase of the CPP. In order to study internal interventions with a detailed water management of the compartment, the model needs to be refined.

4.4.3 DEM for TCM

FAP 19 has developed a detailed DEM for the Tangail Compartment based on BWDB 4":1 mile maps. This will be further refined based upon the needs of the FAP20 modellers and the availability of additional data. Since the elevations used in these DEMs were derived from the BWDB 4 inch series, circa 1960 it is suspected that much has changed in that time. These DEMs will be updated based on the availability of survey data, with priority given to embankment elevations. Existing survey and design data will be reviewed for possible use in these updates. Present day villages not shown on the BWDB maps will be reviewed for additional survey. Villages are typically built up on mounds higher than the surrounding terrain.

Additional surveys may be conducted using GPS and boat. It is thought that flood plain elevation could be most efficiently determined by measuring water depth during wet season, when water level is known. The elevations of the khals might also be measured by boat in the post-monsoon season. The primary purpose of such surveys will be to explore more efficient survey methods, rather than performing comprehensive surveys. Any data collected by FAP 17,18 and 19 having potential use will also be reviewed for possible incorporation into a refined DEM.

Two primary uses of DEMs have been identified by FAP19: for generation of area-elevation curves used by MIKE 11 (Ref. 14), and for creation of flood extent maps from water levels predicted by MIKE 11 (Ref. 15). FAP 25 will explore development applications and procedures that allow FAP 20 staff to utilize DEMs for these purposes on their own equipment with minimal training.

4.4.4 Concept and Methodology

The proposed principle features of the Tangail Compartment FMM will include (ToR, Appendix A):

- location and operation of hydraulic structures, such as gates, major pumps, weirs, etc. in order to predict the effect of various management strategies and operation procedures on the extent, depth and duration of flooding within a specific area.

- capabilities for analysing the agro-economic, infrastructural, etc. implications of various operation and management strategies, including identification of optimal control procedures and responses to alternative remedial measures.
- interface with the Flood Forecasting and Early Warning Models in order to identify appropriate flood preparedness responses, in the planning as well as in the actual operational stages.

The existing model of the Tangail Compartment will be transformed to a tailored pilot FMM. Channels may be added as well as sub-compartment units (rainfall-runoff catchments). The present regulators may be replaced by newly developed, while structure operation rules will be applied.

The output will consist of flood hazard maps for various management/operation strategies. In this way guidelines will be developed for off-line flood management including planning, design, etc. This will also be used as an on-line flood management tool, especially on the effects of operation of control structures, which includes optimization.

4.5 Relation to SWMC and Other FAP Studies

4.5.1 Relation to SWMC

During the course of the FMM project active collaboration will be developed with SWMC. In addition to general support on MIKE 11 use and data transfer the collaboration is being focused to the following activities:

Model Transfer

The latest versions of the General Model and the North Central Regional Pilot Model have already been obtained from SWMC and installed on the FAP 25 computer. It is expected that SWMC will finalize the update and verification of GM by April 1993. This will include revised datums of boundary and comparison water level gauges (Ref. 10), additional river cross[^]sections, revised flood plain delineations etc. Accordingly, the GM setup at FAP 25 will be modified for FMM application. As far as the NCRM is concerned, a full model is not expected before April 1993 and a verified model will only be available by June 1993. (Ref. 11, 12).

Model Refinement

The need for refining the NCRM for FMM application has been explained in Section 4.3. The present study aims at refining the NCRM by utilising the DEM to define flood plain/flood cell characteristics as well as to describe the locations and conditions of major infrastructure such as embankments. As discussed in section 4.3 a major restructuring of the model in terms of flood cell representation may not be fully compatible to SWMC's program. However, SWMC will also benefit from this work. A collaborative program has been discussed with SWMC and the FMM team will help SWMC in analysing the flood plain characteristics by using the DEM.

Data Collection

In general, the FMM study will benefit from the ongoing data collection program of SWMC in the NC Region. New river cross sections to be surveyed by SWMC in the dry season as well as the hydrometric data to be collected during the monsoon of 1993 will be useful for the FMM. In response, FAP 25 will provide SWMC with any new information or data obtained from field or from the DEM analysis. Embankment locations and their physical conditions will be some of the data to be collected by FAP 25, which will be of interest to SWMC.

Specifically for the NCRM, a mutually beneficial data collection program has been planned (Appendix D-2). SWMC has agreed to carry out the additional data collection for FAP 25, the expenses of which will be covered by the FMM budget.

Since the current project SWSMP-II under SWMC will end in November 1993, cooperation beyond that period cannot be worked out at present.

Training

Use of FMM in SWMC's in-house training may be possible during SWSMP-III phase in 1994 (if the new phase is materialized).

Institutional

SWMC is a strong candidate for the host of FMM after FAP 25. However, the institutional affiliation of SWMC and its geographic location will be a deciding factor. The SWMC has recently been placed under the administrative umbrella of the River Research Institute (RRI) in Faridpur. The concern in this respect is the future institutionalization of the FMM. According to the TOR, FMM would be maintained and updated by SWMC, subject to the final recommendations of FAP 26. At the present time no firm recommendations for the future institutional structure of the modelling activities as well as the end users of FMM have resulted from FAP 26.

4.5.2 *Relation to FAP 10 / BWDB-FF&WC*

The TOR envisages FAP 10- Flood Forecasting and Warning to test the FMM for North Central Region and the GM-FMM for inundation forecasting. Since, the FAP 10 project terminated by November 30, 1992, the Flood Forecasting and Warning Center (FF&WC) of BWDB has been approached and modes of cooperation discussed. Po^Xtitive interests have been expressed by the Chief Engineer, Hydrology and the Directors of Surface Water Hydrology (SWH) I and II regarding cooperation with FAP 25. The following cooperations have been agreed.

FF&WC will test the FMM developed at FAP 25 for real time flood forecasting with the help of FAP 25. For this a few Engineers of the FF&WC (BWDB) trained in MIKE 11-FF modelling will be deputed to work at FAP 25 after October 1993. They will learn the FMM technology and apply in real time forecasting.

- FF&WC will supply the GM-FF and all the data (including real time) needed for making the test runs of the FFM.
- FF&WC will actively participate in the FMM Workshops.
- FAP 25 and FF&WC will cooperate in the modelling work (especially, in the interfacing of MIKE 11 -DEM) of the new FAP 10 project.

A draft TOR for the continuation of FAP 10 project as 'Development of Flood Warning Services to Improve Public Safety' has been prepared (Ref. 13). Possible donors have been approached, but the final TOR has not yet been approved. As stated in the draft TOR most of the modelling activities for improved forecasting are similar to those of the FMM project. The recent CAT Mission (Ref. 10) has recommended a "closer examination of the TOR of FAP 10 to avoid unnecessary duplication of activities between FAP 10 and FAP 25 (FMM)". Thus, it is expected that in due course of time a strong collaboration will be developed between the FMM project and the new FAP 10.

4.5.4 Relation to FAP 19

FAP 19 has proven the concept of using DEMs to generate area/elevation curves and flood extent maps (Ref. 14). Other projects have expressed interest in incorporating DEMs into their modelling activities, in particular, SWMC, FAP 3 and FAP 20. These other projects do not have the resources to devote to become fully familiar with GIS. It took FAP 19 staff many weeks of training before they could create these products.

FAP 25 intends to develop "applications" that allow modellers to generate area/elevation curves and flood extent maps without intimate knowledge of GIS; the complexities of GIS will be "hidden" from the user behind menu driven interfaces. These applications will be developed using the workstation version of ARC/INFO, which has a macro language for building menu driven graphic user interfaces (GUIs). FAP 19 uses the PC version of ARC/INFO, which has a very limited macro language.

FAP 19 has also implemented an image processing system (Ref. 14). This system allows "images" collected by satellites to be classified to portray different types of land cover such as charland, water, vegetation. FAP 25 does not plan on, nor is technically equipped, to do image processing. FAP 25 will have a need for classified images, sometimes called "grids", that may be easily used in assessing potential flood impact. The same routines that generate area elevation curves can easily generate cropped-area elevation curves or inundated population elevation curves, but only if crop grids and population grids are available.

Of particular interest are "radar" images that have been collected by satellite and can be processed to show actual flood extent - even on cloudy days. Again, FAP 25 can use the processed images, but is unable to do the image processing.

It is anticipated that many of the applications developed by FAP 25 on ARC/INFO will be "ported" to the PC. There is an inexpensive GIS package called Idrisi that can use classified images as well as "vector" data, such as roadways and drainage networks. Idrisi lacks a

macro language, but customized menus can be written in Pascal. Functions used in the ARC/INFO language but not present in Idrisi can also be added as Pascal programs when necessary. FAP 19 uses the Idrisi package and has conducted training courses in its use. Even with menu interfaces, there will still be a need for training. FAP 25 does not plan on conducting training sessions, but is interested in supporting training efforts of FAP 19 in this regard.

4.5.5 *Relation to FAP 20*

The existing Tangail Compartment Model has been developed by FAP 20 for planning and design. FAP 20 will make available, free of charge, the developed model and all field data being and to be collected for the compartment model and undertake additional field data collection as may be required for the FMM development of the Tangail compartment. FAP 20 provides, free of charge, 12 m-m of a qualified Modelling Engineer (FCD Engineer II), 24 m-m of a qualified local Modelling Engineer (Modelling Engineer II) and 2 m-m of short term experts.

4.5.6 *Relation to Other FAPs*

Apart from the integrated support from the above mentioned projects, indirect support for the FMM development as well as use of some of FMM facilities in envisaged from the following FAP projects:

- FAP 1 Brahmaputra River Training Study
- FAP 2 North West Regional Study
- FAP 4 South West Area Water Resources Management Project.
- FAP 6 North East Regional Study

As mentioned in Section 4.2 above, up to date information on existing embankments and other major infrastructure are being obtained from the above studies. Also, to test GM-FMM for future development scenarios, actions proposed by the above FAPs will be studied.

- FAP 12 FCD(I) Agricultural Study
- FAP 13 Operation and Maintenance Study
- FAP 14 Flood Response Study

These FAPs have submitted their final reports. However, based on their studies, secondary data on cropping patterns, flood impact, structure operation, socio economic data etc. will be obtained for the application of FMM at a later stage for impact analyses.

FAP 17 Riverine Floodplain Fisheries Study and Pilot Project:

A series of meetings have been held with the FAP 17 consultants to discuss possible collaboration, particularly to use the FMM output in studying the impact of flooding on flood plain fisheries. FAP 17 are also interested to use the GIS facilities at FAP 25. Negotiations are going on to develop a field campaign at selected areas (in Tangail and NC

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Region) to collect data on flood extent and depth in flood plains during the entire wet season of 1993. This will provide a useful feedback to check the accuracy of flood mapping by FMM. Also, discussion are underway exploring the possibility of using Radar Imagery to compare flood plain inundation.

FAP 24 River Survey Program

FAP 24 have been approached for their expert advise on possible use of GPS in surveying embankments, infrastructure and flood cells. They have offered to let FAP 25 use their GPS equipment for field trials. GPS in a differential mode is being tested in conjunction with traditional land surveys to locate the embankments, and measure the gaps, elevations etc.

Is FPCO
aware of this?

5. WORK PROGRAMME

5.1 Introduction

This chapter describes how FAP 25 will reach its objectives and produce the outputs (FMM) described in the preceding chapters. The chapter includes.

- * Work Breakdown Structure
- * Project Implementation Team Organization
- * Work Schedule
- * Professional Resource Allocation
- * Work Program; and
- * Summary of Administrative and Logistical Support Requirements

It should be noted that the FAP is a dynamic process. This means that certain conditions at the time of this report writing are undergoing or will change. For example, the application of FMM for real time flood forecasting will very much depend on the resumption of FAP - 10 work. Similarly, FMM activities will also be affected by SWMC' future plan including their geographical location. Accordingly changes that occur after inception will need to be incorporated appropriately in the work program.

5.2 Work Breakdown Structure

The work programme has been broken up into a three level hierarchy of activities, tasks and sub-tasks. An activity is made up of a number of tasks which in turn are made up of a number of sub-tasks.

The activities (Table 5.1 and Figure 5.1) represent the seven main areas of work: management; FMM development; FMM application at a national, regional and sub-regional levels; workshops and documentation.

The tasks and sub-tasks of each activity are documented in section 5.6.

Table 5.1 Summary of Work Programme Activities

Code	Activity	Description
100	Management	Administration, progress monitoring and ensuring all activities, tasks and sub-tasks are completed on-time.
200	FMM Development	Development of the FMM.
300	FMM GM Application	Application of the FMM on a national level using the General Model.
400	FMM NCRM Application	Application of the FMM on a regional level using the North Central Regional Model.
500	FMM TCM Application	Application of the FMM on a sub-regional level using the Tangail Compartment Model.
600	Workshops	Organisation and management of workshops.
700	Reporting	Documentation, publication and dissemination of reports and training material.

5.3 Organization

The FMM project Implementation Team consists of the members of DHI and their collaborating partners EUROCONSULT and BCEOM plus local professional staff. Figure 5.2 shows the overall Organization of the team with its relation to the Donors and the Executing agency. The team leader is responsible for the overall management of the project. The local hydraulic modelling engineer who is responsible for FAP model coordination under FAP 25 is also the Deputy Team Leader of the FMM project.

The French support is provided through the input of the Flood Control and Drainage Engineer (FCD - I). The inputs of FCD - II and a local modelling engineer are supported by the Netherlands through FAP 20 (CPP). The home office support is provided by the Head of the River Hydraulics Department at DHI, Denmark. Job descriptions for each of the professional positions are given in Appendix B.

5.4 Work Schedule

The overall work schedule for the project is shown in Figure 5.3. The project has started on 19th october 1992 and is scheduled to be completed by 18th October 1994.

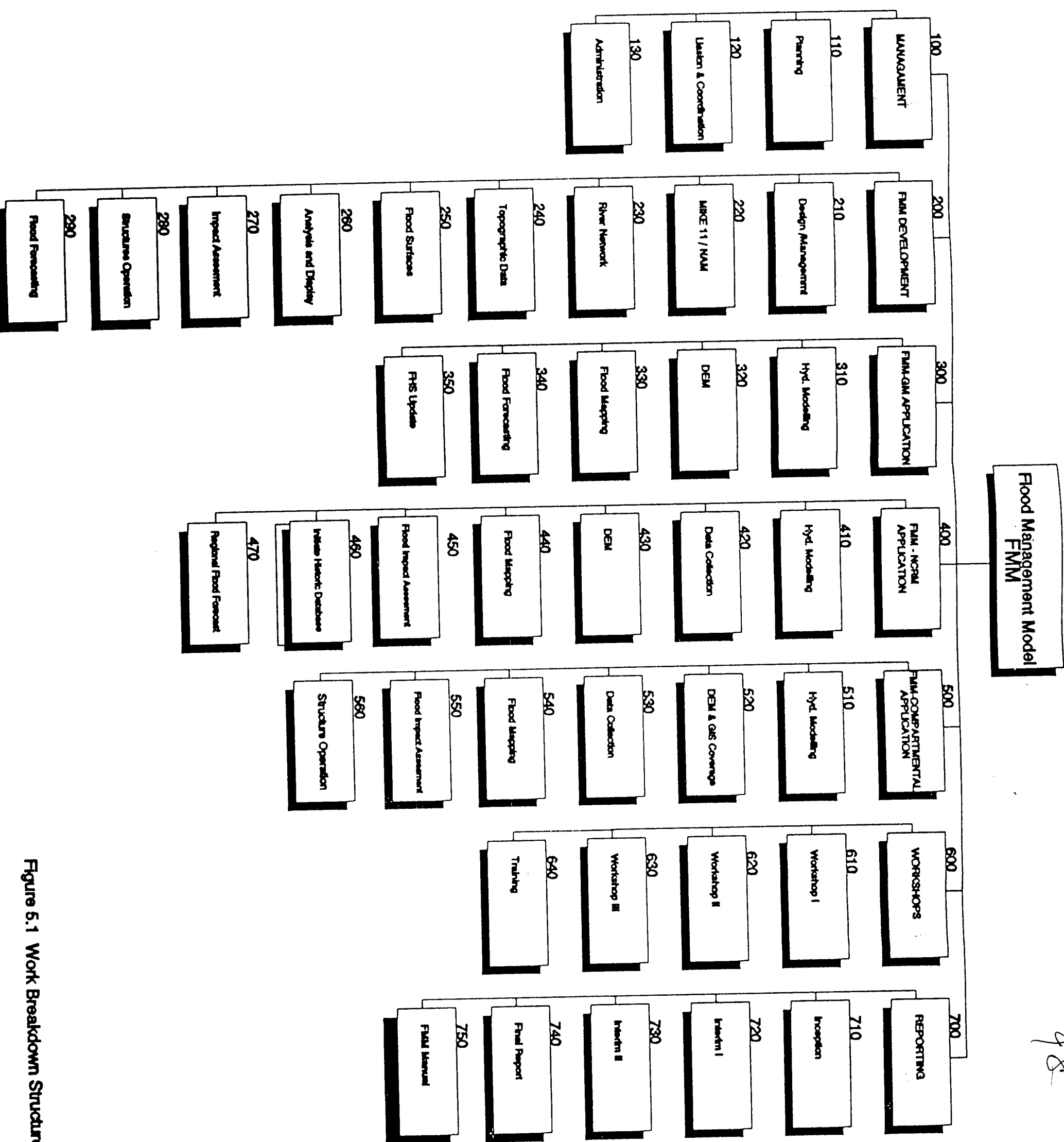
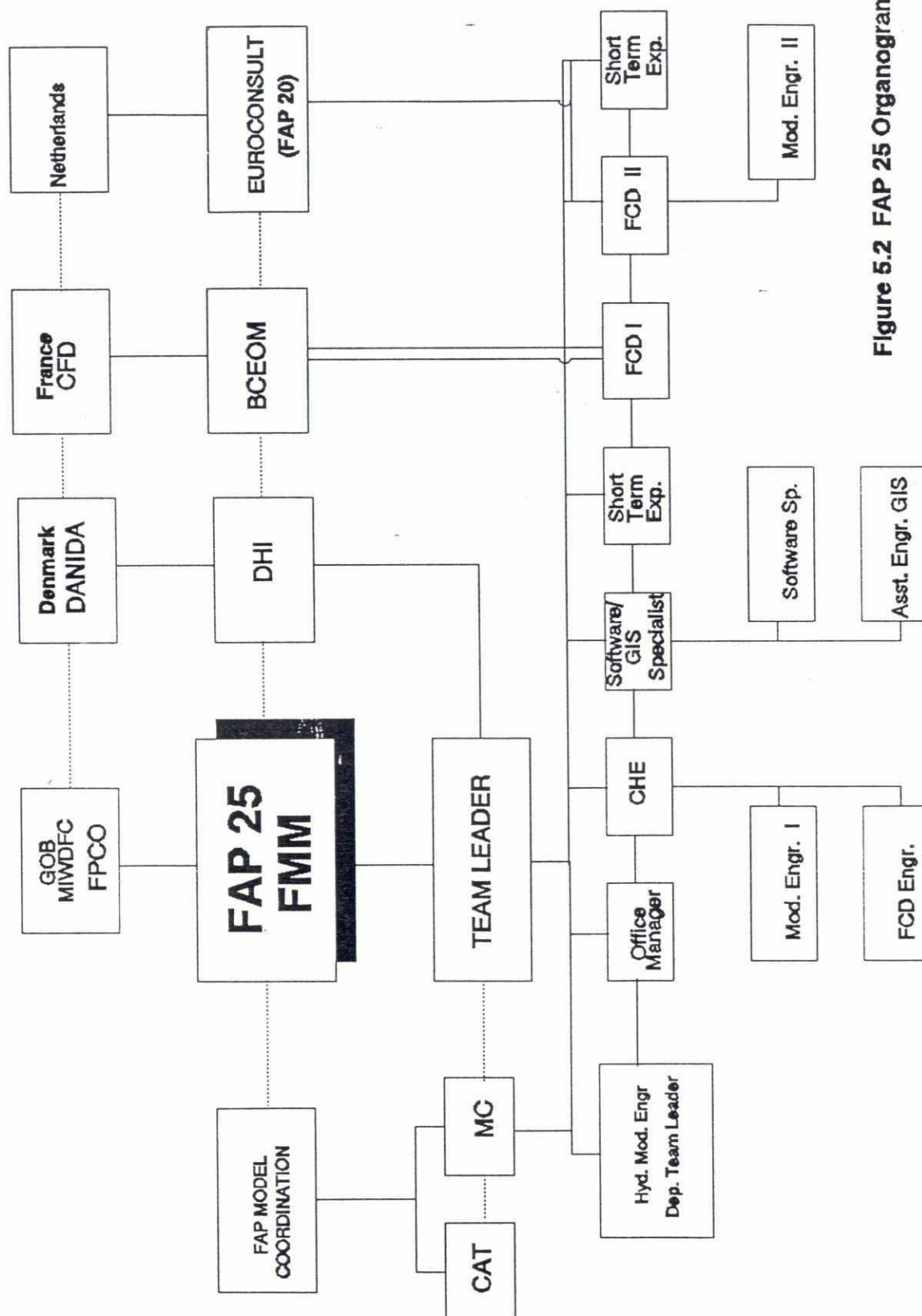


Figure 5.1 Work Breakdown Structure



Activity Schedule

5-6

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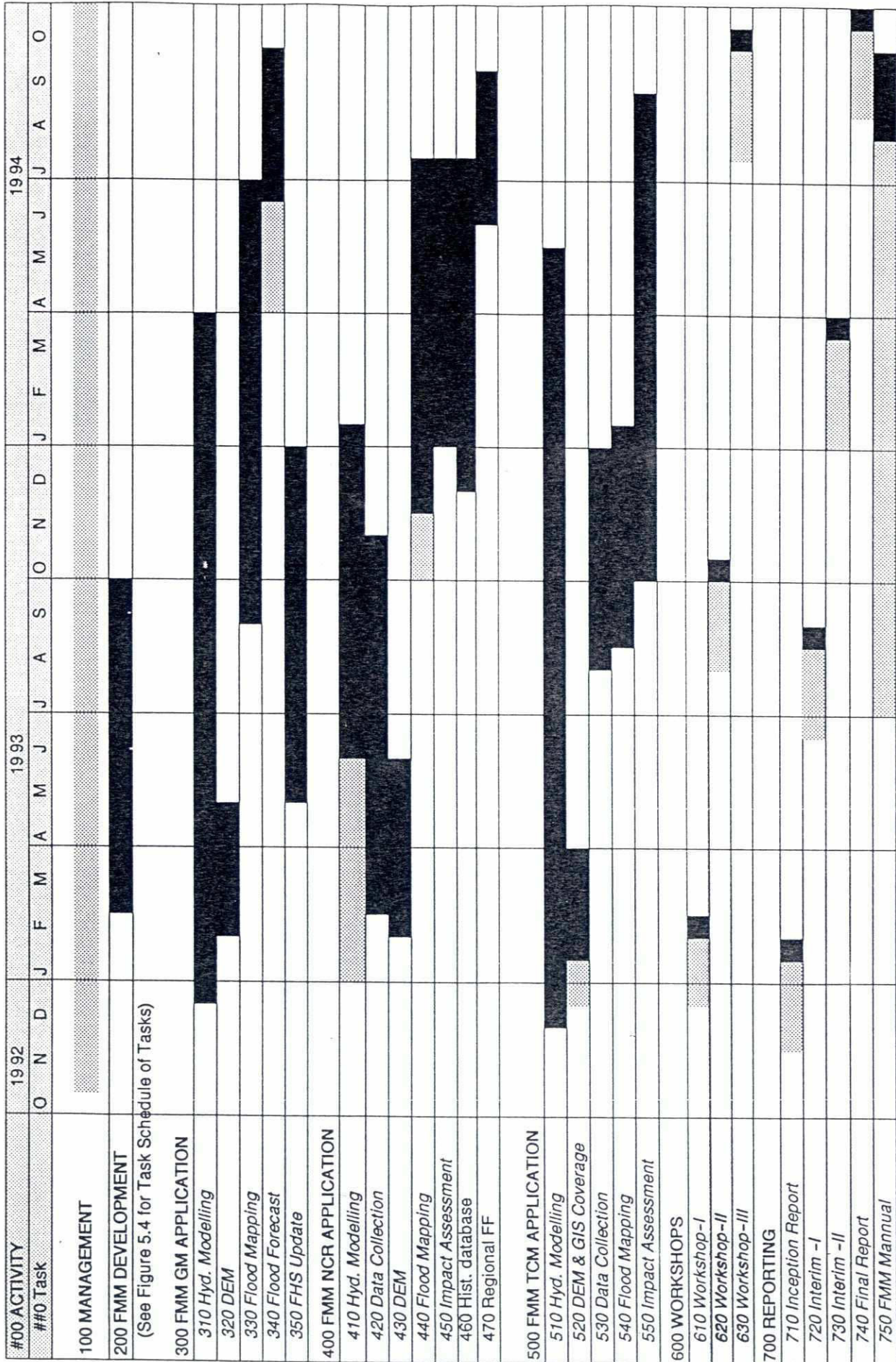


Figure 5.3 Activity Schedule

5.5 Professional Resource Allocation

The deployment of the professional resources over the two year project period is shown on Figure 5.4a (Local staff) and 5.4b (expatriate staff). The figures also show the starting date of the staff and their total input to the project. It should be noted that the team leader's input to FAP-25 is part time, though he is full time stationed in Dhaka. The other half of his time is spent in SWMC and other DHI projects in Bangladesh. The schedules of short term experts are tentative and will be reviewed during the course of time.

5.6 Work Program

This section describes the methodology planned for each activity/task shown in Figure 5.1. A uniform format is used to present this information. The format can also be seen as a summary work package sheet for each task, which briefly describes the methodology, including activity/task name and code, definition, objectives, assumptions, linkages, responsibility center, outputs, time frame and the professional resource allocation to the task.

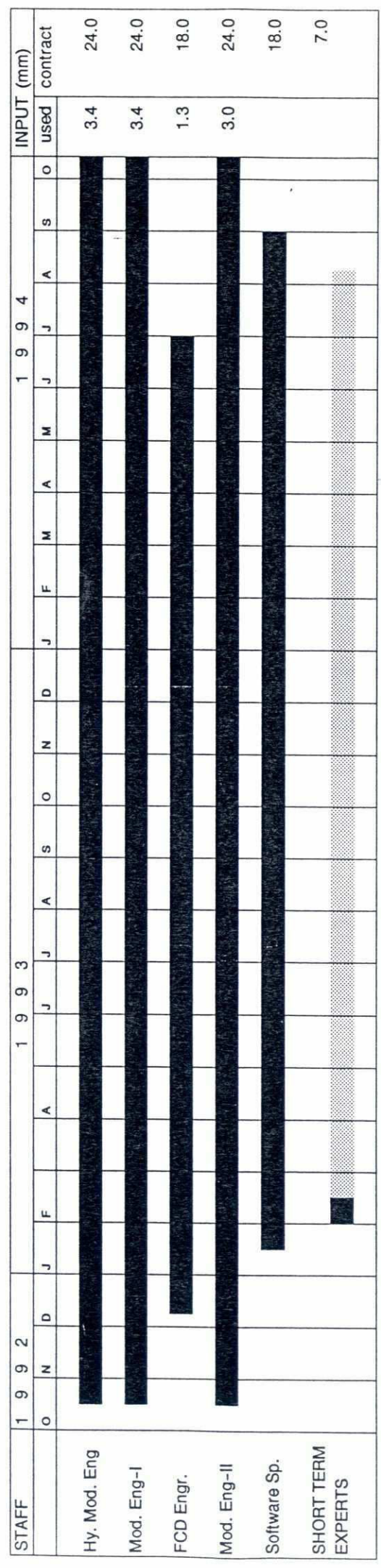
A linkage signifies that regular Communication and Coordination are scheduled between the task group responsible for the work named at the top and the groups responsible for those activities/tasks specified under the "linkage" heading.

Responsibility Center is the person to whom responsibility for the outputs of the work package is assigned. In this regard, responsibility centers for all work assigned to expatriate professional staff.

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DANISH HYDRAULIC INSTITUTE
FLOOD MANAGEMENT MODEL
PROJECT NO ==> 6975
PLAN OF LOCAL STAFF INPUT

DATE ==> 31 / 01 / 93



Full Time Input
Part Time Input

Figure 5.4a Schedule of Local Staff Input

DATE ==> 31/01/93

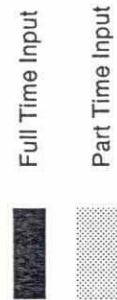


Figure 5.4b Schedule of Expat. Staff Input

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5.6.1 Activity 100 - Management

Definitions Management refers to project management - that is - the process of monitoring, coordinating and controlling the inputs to and outputs from the project as described in the TOR.

Objectives Effective and timely completion of FMM objectives

Assumptions Resources to be managed include only those funded by DANIDA. It is assumed that the French and the Dutch Supports are available in harmony with the project schedule.

Results/Outputs Plans, Schedules, Reports

Linkages With all other project activities

Responsibility Team Leader

Timeframe Duration of the Project

Resources

Professional Resource	Man month
Team Leader	6
Home Office Support	3
Deputy Team Leader	12

The management activity is broken down into three tasks as described in Table 5.2. In addition to the professional resources, considerable effort will be supplied under this activity by local support staff for administration and reporting.

Table 5.2 Activity 100 - Management

Code	Activity	Description
110	Planning	Planning of resources.
120	Liaison and Coordination	Liaison and coordination with other FAP projects, SWMC and other government and non-government organisations.
130	Administration	Day to day office administration.

5.6.2 Activity 200 - FMM Development

Definitions FMM Development: The design and development of computer software incorporating new techniques in the field of flood management for Bangladesh. Special emphasis is being directed towards enhancing existing river modelling practices, floodplain management, FCD structure operations and flood forecasting.

Objectives To produce a user-friendly, robust and low maintenance product for use by computational hydraulics specialists, GIS specialists and technicians.

Prerequisites MIKE11-GIS.

Results/Outputs ARC/INFO and MIKE 11 application developments; Documentation.

Linkages Activities 300, 400, 500, 600, 700

Responsibility Computational Hydraulics Engineer

Timeframe 7.5 months

Resources

Professional Resource	Man Months
Team Leader	3.5
Computational Hydraulics Engineer	7.0
Software Specialist	7.0
Software Specialist (local)	7.0*
Asstt. Engr. (GIS) (local)	7.0†
Short Term Expert (NAM)	1.0
Short Term Expert (Agriculture)	0.5
Short Term Expert (Structures)	1.5
Short Term Expert (Optimisation)	1.0
FCD Engineer II	0.5

* - 1.5 mm allocated to computer system administration and in-house training

† - 1.0 mm allocated to in-house training using ARC/INFO

Table 5.3 Activity 200 - FMM Development

Code	Task	Description
210	Design & Management	FMM system design and management.
220	MIKE 11 / NAM	Database interface between MIKE 11 and ARC/INFO.
230	River Network	Graphic environment for digitising/editing MIKE 11 model network, FCD structure locations and NAM catchments. Creation of water surface GRID for generating flood surfaces.
240	Topographic Data	Topographic data extraction and display from DEM and export to MIKE 11 topographic data base.
250	Flood Surfaces	Import of MIKE 11 hydrodynamic output and generation of flood level, depth and duration surfaces.
260	Analysis and Display	General viewing environment for analysis and display of flood surfaces. Display of MIKE 11 hydrodynamic output as time series and profiles and statistical analysis. Viewing control will be in a graphical environment depicting the river network.
270	Impact Assessment	Analysis of flood surface scenarios producing impact surfaces such as change in flood levels, crop damage.
280	Structure Operation	Improved structure representation in MIKE 11 for application in Bangladesh. Special MIKE 11 add-on module for the on-line control of FCD structures during a MIKE 11 simulation.
290	Flood Forecasting	Development of logic and methodology for applying the FMM to flood forecasting.

Task 210 - Software Design and Resource Management

Definitions Software Design: Design specifications for software development including testing, validation and documentation procedures.

Resource Management: Management of professional and computer resources during FMM development.

Objectives To ensure a coordinated and structured development of the FMM.

Prerequisites None

Results/Outputs Software development specifications; Documentation.

Linkages None

Responsibility Computational Hydraulics Engineer

Timeframe Duration of FMM development

Resources

Professional Resource	Man Months
Team Leader	0.5
Computational Hydraulics Engineer	1.0
Software Specialist	1.5
Software Specialist (local)	0.5
Asstt. Engr. (GIS) (local)	0.5

210 Sub-Tasks

Code	Sub-Task	Duration (Weeks)	Description
211	Software Design Specifications	2.0	Documentation of specifications for the design, development, testing and validation of software.
212	Database Design	3.0	Design of database links between MIKE 11 and ARC/INFO.
213	Schedule Update	1 h/w	Updating and monitoring of work schedule. (A draft work schedule is presented in Figure 5.5)
214	Coordination / Meetings	2 h/w	Coordination of resources through liaison and regular meetings.
215	Quality Control	1 h/w	Quality check all developments.
216	Porting to Other Systems	2.0	Assessment and recommendations on porting the FMM to other, less expensive systems, especially in light of implementation of the FMM in field offices.
217	In-house Training	1.0	In-house training of staff who will be applying the FMM during the FMM application phase. Training material will also be used for the Second Workshop.
219	Documentation	2.0	Introductory and background documentation and coordination of documentation for all the 200 tasks.

h/w = hours per week

Task 220 - MIKE 11 / NAM

- Definitions** MIKE 11: River modelling program
NAM: Catchment hydrology and management program.
- Objectives** Development of features in MIKE 11 and NAM to help model the flooding of rivers and floodplains in Bangladesh.
- Prerequisites** MIKE 11 and NAM; Sub-task 244
- Results/Outputs** Specialised functions in MIKE 11 and NAM.
- Linkages** Tasks 410, 510
- Responsibility** Computational Hydraulics Engineer
- Timeframe** 1 month

Resources

Professional Resource	Man Months
Computational Hydraulics Engineer	0.25
Short Term Expert (NAM)	1.0

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220 Sub-Tasks

Code	Sub-Task	Duration (Weeks)	Description
221	MIKE 11 / NAM Interface	4.0	Development of an interface linking MIKE 11 and NAM and new functions in NAM to model the interaction between rainfall and river flooding.



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Task 230 - River Network

Definitions River network: Network of MIKE 11 cross-sections and branches, and storage cells, NAM catchments and FCD structures connected to the network.

Objectives Develop a system for digitising and editing a river network and from which a 3-D water surface can be generated.

Prerequisites Sub-task 211

Results/Outputs ARC/INFO AML code; Documentation.

Linkages Tasks 240, 260, 310, 410, 510

Responsibility Computational Hydraulics Engineer

Timeframe 2 months

Resources

Professional Resource	Man Months
Computational Hydraulics Engineer	1.0
Software Specialist	1.0
Software Specialist (local)	2.0
Asstt. Engr.(GIS) (local)	1.0

230 Sub-Tasks

Code	Sub-Task	Duration (Weeks)	Description
231	River Network Editor	2.0	An editor for digitizing/editing the schematic representation of a MIKE 11 model network showing cross-sections and branches in plan view.
232	Storage Cell Editor	1.0	An editor for digitising/editing a coverage depicting storage cells linked to cross-sections. The storage cells will be used to delineate polygons for calculation of area-elevation curves (Sub-task 242).
233	FCD Structures Editor	1.0	An editor for digitising/editing of a coverage showing FCD structure types and mode of operation.
234	NAM Catchment Editor	1.0	An editor for digitising/editing of a coverage showing NAM catchment boundaries. This coverage will be used by Sub-task 244 for calculating catchment areas.
235	Rain Gauge Editor	1.0	An editor for digitising/editing of a coverage depicting locations of rain gauges and linking them to MIKE 11's boundary data base for use in Sub-task 264.
236	Water Surface GRID	3.0	Transformation of the trial water surface TIN created by MIKE11-GIS to a GRID which will act as a template for high speed generation of flood surfaces.
239	Documentation	2.0	Documentation of User's Guide including tutorials.

*Task 240 - Topographic Data***Definitions**

Topographic Data:

DEM: 3-D surface of floodplain terrain including features such as embankments and levees.

MIKE 11: Profiles at selected river and floodplain cross-sections and storage area versus elevation curves representing the storage capacity of the river and floodplain.

NAM: Catchment and flooded areas.

Objectives

To extract topographic data from a DEM in suitable formats for export to MIKE 11 and to import MIKE 11 river cross-sections into ARC/INFO.

Prerequisites

Task 230

Results/Outputs

ARC/INFO AML code; Documentation.

Linkages

Tasks 310, 410, 510

Responsibility

Computational Hydraulics Engineer

Timeframe

2 months

Resources

Professional Resource	Man Months
Team Leader	0.5
Computational Hydraulics Engineer	0.5
Software Specialist	1.5
Asstt. Engr.(GIS) (local)	2.0

240 Sub-Tasks

Code	Sub-Task	Duration (Weeks)	Description
241	DEM Cross-sections Profiles	1.0	Extraction of cross-section profiles from a DEM and export to MIKE 11.
242	DEM Area-Elevation Curves	1.0	Calculation of flooded area versus elevation curves from a DEM and export to MIKE 11.
243	Import MIKE 11 Cross-sections	1.0	Import of MIKE 11 cross-sections from its topographic data base for display in ARC/INFO.
244	DEM NAM Data	1.0	Calculation of catchment areas and flooded areas of catchments and export to NAM.
245	Embankment Survey Capture	2.0	Automatic processing of embankment surveys provided in X-Z format into a DEM (X-Y-Z format).
249	Documentation	2.0	Documentation of User's Guide and methodologies adopted.

Task 250 - Flood Surfaces

Definitions Flood Surfaces: 3-D surfaces of flood levels, flood depths and flood durations based on MIKE 11 output.

Objectives To generate flood level, flood depth and flood duration surfaces using the water surface GRID created from a river network (Sub-task 236).

Prerequisites Sub-task 236.

Results/Outputs ARC/INFO AML code; Documentation.

Linkages Tasks 260, 270, 330, 440, 450, 540, 550

Responsibility Computational Hydraulics Engineer

Timeframe 2 months

Resources

Professional Resource	Man Months
Team Leader	0.5
Computational Hydraulics Engineer	1.0
Software Specialist (local)	2.0

250 Sub-Tasks

Code	Sub-Task	Duration (Weeks)	Description
251	Data Transfer (MIKE 11 to ARC/INFO)	2.0	Transfer of MIKE 11 hydrodynamic results and boundary data base to ARC/INFO.
252	Data Management	1.0	Design database structure for storage and management of large numbers of flood surfaces.
253	Flood Level Surfaces	2.0	Generation of water surface based on MIKE 11 water levels using the water surface GRID (Sub- task 236).
254	Flood Depth Surfaces	0.5	Generation of flood depth surfaces by subtracting the DEM from a flood level surface.
255	Flood Duration Surfaces	2.0	Generation of flood duration surfaces by relating flood depths over time with the DEM.
259	Documentation	2.0	Documentation of User's Guide and methodology.

Task 260 - Analysis and Display

Definitions Analysis: GIS analysis of flood data in relation to other flood surfaces and to agriculture, fisheries and socio-economic data.

Display: Display of flood and other data in 1-D, 2-D and 3-D formats.

Objectives To utilise GIS analysis tools and display functions for rapid assessment of flood data and their relationship to other data in 1-D, 2-D and 3-D viewing environments.

Provide the basis and viewing environment for the impact assessment (Task 260) facilities.

Prerequisites Tasks 230, 250

Results/Outputs ARC/INFO AML code; Documentation.

Linkages Tasks 270, 310, 330, 340, 410, 440, 450, 510, 540, 550

Responsibility Computational Hydraulics Engineer

Timeframe 2 months

Resources

Professional Resource	Man Months
Team Leader	0.5
Computational Hydraulics Engineer	1.0
Software Specialist	1.5
Asstt. Engr.(GIS) (local)	2.0

260 Sub-Tasks

Code	Sub-Task	Duration (Weeks)	Description
261	Viewing Environment	2.0	Design layout of viewing environment using the river network as the background from which data sets can be geographically selected and displayed. Incorporate basic functions such as setting of colour, line and shade types, text, pan/zoom and map compiler.
262	Flood Mapping	2.0	Display of flood level, flood depth and flood duration surfaces.
263	Flood Profiles	1.0	Display of flood and ground profiles along a line digitised over a surface.
264	Time Series Data	1.0	Display of flood levels, depths and discharges at selected locations on the river network and rainfall at selected rain gauge sites.
265	Statistical Analysis	1.0	Statistical analysis and display of flood data.
269	Documentation	2.0	Documentation of User's Guide and methodologies adopted.

Task 270 - Impact Assessment

Definitions Impact Assessment: Comparison of flood data for "before" and "after" scenarios to establish the impacts on flood levels, velocities and discharges of proposed flood management schemes.

Use these impacts to estimate damages/benefits to agriculture, fisheries and infrastructure.

Objectives To use GIS analysis tools for calculating differences between flood surfaces from which flood impacts and an estimate of damages/benefits to agriculture and fisheries may be made.

Use the GIS display tools developed in Task 260 for presenting impacts.

Prerequisites Tasks 250, 260

Results/Outputs ARC/INFO AML code; Documentation.

Linkages Tasks 450, 550

Responsibility Computational Hydraulics Engineer

Timeframe 1.5 months

Resources

Professional Resource	Man Months
Team Leader	0.5
Computational Hydraulics Engineer	0.5
Software Specialist	1.5
Software Specialist (local)	1.0
Asstt. Engr.(GIS) (local)	1.0
Short Term Expert (Agriculture)	0.5

270 Sub-Tasks

Code	Sub-Task	Duration (Weeks)	Description
271	Data Library Management	1.0	Design database structure for incorporating other data sets: agriculture, fisheries and infrastructure.
272	Flood Level Impact Mapping	1.0	Display of contours depicting the change in flood levels between two MIKE 11 simulations thus showing regions of increased or decreased flood level.
273	Crop Damage Mapping	2.0	Using a relationship between flood depth and/or duration and crop damage/benefit to produce a crop damage map.
274	Fisheries Damage Mapping	1.0	Using a relationship between flood depth and/or duration and fisheries yield reduction/increase to produce a fisheries damage map.
279	Documentation	2.0	Documentation of User's Guide and methodologies used.

Task 280 - FCD Structures Operation

- Definitions** FCD Structures: Flood control and drainage structures..
- Operation: The daily operation of structures for flood mitigation and irrigation including maintenance schedules and structure failures.
- Objectives** Develop a simple interactive system within MIKE 11 for monitoring and upgrading FCD structure operation schedules prior to or during a MIKE 11 simulation.
- Extend MIKE 11's structure routines to suit typical FCD structures found in Bangladesh.
- Prerequisites** None
- Results/Outputs** Specialised MIKE 11 add-on module; Documentation.
- Linkages** Task 550
- Responsibility** Computational Hydraulics Engineer
- Timeframe** 2 months
- Resources**

Professional Resource	Man Months
Team Leader	0.5
Computational Hydraulics Engineer	1.5
Short Term Expert (Structures)	1.5
Short Term Expert (Optimisation)	1.0
FCD Engineer II	0.5

280 Sub-Tasks

Code	Sub-Task	Duration	Description
281	Composite Structures	3.0	Develop structure routines to model a composite of structures at a single Q-point.
282	Embankment Breaching	2.0	Develop an embankment breaching routine.
283	Structure Operation Design	1.0	Design new MIKE 11 menus and structure of software for an interactive operation of FCD structures. This will include a simple user interface for changing the operation status of structures prior to or during a simulation and an on-line display of selected water levels, discharges and structure openings.
284	Structure Operation Facility	3.0	Develop structure operation facility.
285	Optimisation	3.0	Develop methodologies for optimisation of structure operations. Develop a prototype application.
289	Documentation	1.0	Documentation of User's Guide and technical reference.

Task 290 - Flood Forecasting

- Definitions** Flood Forecasting: Forecast of flood levels on a national and regional level.
- Objectives** To outline possible uses and methodologies for using FMM facilities during flood forecasting, for example: the on-line production of flood inundation maps.
- Prerequisites** Tasks 230, 250, 260
- Results/Outputs** Recommended procedures for using the FMM during flood forecasting.
- Linkages** Task 340
- Responsibility** Computational Hydraulics Engineer
- Timeframe** 0.5 months

Resources

Professional Resource	Man Months
Team Leader	0.5
Computational Hydraulics Engineer	0.25

290 Sub-Tasks

Code	Sub-Task	Duration (Weeks)	Description
291	Logic / Methodology	2.0	Develop logical rules and methodologies for applying the FMM during flood forecasting. Outline advantages and limitations.

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5.6.3 Activity 300 - FMM GM Application

This activity is broken down into the following tasks

Table 5.4 Activitys 300 - FMM GM Application

Code	Task	Description
310	Hydraulic Modelling	Acquisition, setting up and simulation of the MIKE 11 GM.
320	DEM	Acquisition and assessment of GM DEM.
330	Flood Mapping	Flood mapping on a national level using the RMM and assessment of accuracy.
340	Flood Forecasting	Application of the FFM in conjunction with FAP10.
350	FHS update	Carry out 25 years simulation using GM to update the Results and Analysis of Flood Hydrology Study (FHS)

Task 310 - Hydraulic Modelling

Definitions The application of FMM on the national level is based on the General Model (GM) developed at SWMC. The GM includes the NAM - Hydrological Module and the HD - the hydrodynamic module.

Objectives To make GM operational at FAP - 25 and to produce output required for FMM application.

Prerequisites Transfer of updated model and data from SWMC.

Results/Outputs Water levels at all computational nodes of the GM for selected historical flood events and for selected scenarios.

Linkages Tasks 120, 220

Responsibility Computational Hydraulic Engineer

Time frame 3 Months

Resource

Professional resource	Man month
Team Leader	0.5
Comp. Hyd. Engr.	0.5
Modelling Engineer -1 (Local)	3
Hyd. Modelling Engr.(Local)	0.5

Sub-tasks

Code	Sub-task	Duration (Month)	Description
311	Model Transfer	0.5	Transfer the updated GM including data from SWMC and install at FAP 25 Computer (Workstation)
312	Simulation	0.5	Simulate Historical Flood events (1986 - 1992) and ensure that the results are the same as those of SWMC.
313	Improvement	1	Attempt to improve the simulation in the right bank flood plain of Jamuna and around Greater Dhaka.
314	Embankment Scenarios	0.5	Simulate impacts of embankments along the major rivers

Task 320 - DEM for GM

Definitions The Digital Elevation Model (DEM) to be used for FMM - GM is the course DEM for Bangladesh based on MPO 1 km grid and established by FAP 19.

Objective To transfer the DEM from FAP 19 and install it in the FAP 25 computer and assess its usefulness and incorporate major structures (e.g. Embankments).

Prerequisites Availability of the DEM at FAP 19 and their cooperation in transferring the data.

Results/Output DEM for the entire country (GM area)

Linkages Tasks 120, 310, 330

Responsibility Software specialist

Time frame 1 Month

Resources

Professional Resource	Manmonth
Software specialist (expert)	0.25
Modelling Engr. - I	1
Assistant Engineer (GIS)	0.5

Sub-tasks

Code	Sub-task	Duration	Description
321	DEM - Transfer	1 week	To transfer the DEM from FAP 19 to FAP 25 Computer,
322	River Network	2 weeks	Digitize the river network, X - section locations of GM and incorporate in the DEM
323	Improvement8	1.0	Collect existing Embankment locations and conditions and incorporate in the DEM
324	Planned Embankment	0.5	Incorporate the future Embankment options in the DEM



Task 330 - Flood Mapping

Definition The flood plain inundation maps will be derived for the existing conditions and a few embankment scenarios by superimposing the water surface derived from the GM upon the coarse DEM.

Objectives To demonstrate the application of FMM on a national level.

Assumptions

Results/Output Flood Maps

Linkages Tasks 220, 230, 310, 320

Responsibility Computational Hydraulic Engineer

Timeframe 1 Month

Resources

Professional Resource	Man Month
Team Leader	0.25
Comp. Hyd. Engr.	0.25
Modelling Engineer - 1	12
FCD Engineer (Local)	0.25
Assistant Engineer.(GIS)	0.5

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Sub-tasks

Code	Sub-task	Duration	Description
331	Network in GIS	3 days	Digitize Mike11 Network
332	Flood Surface	2 Weeks	Elaborate Mike11 results
333	Flood Maps	4 Weeks	Create Flood maps for various scenarios
339	Documentation	2 Weeks	Prepare guidelines

Task 340 - Flood Forecasting

Definition The methodology and the tool (FFM) will be developed at FAP - 25. Application of FFM will be done by BWDB, Flood Forecasting and Warning Center.

Objectives To demonstrate the applicability of FMM in real time flood forecasting. To develop a basis for the long term goal of FMM project (on-line flood forecasting and management).

Assumptions The application of FMM - GM to real time flood forecasting will be done by BWDB.

Results/Output Real-time forecast of flood plain inundation .

Linkages Tasks 120, 250, 310, 320, 330,

Responsibility Computational Hydraulic Engineer

Timeframe 2 Months

Resource

Professional Resource	Man Month
Team Leader	0.5
Comp. Hyd. Engr.	0.5
Modelling Engineer -1	1
Staff of BWDB, FFWC	to be allocated

Sub-Tasks

Code	Sub-task	Description
341	GM - FF	Acquire the flood forecasting version of GM (GM - FF) available at FAP - 10 and convert into HP - UX and reproduce results for past data.
342	FFM	Incorporate the developed FFM methodology into GM-FF with the DEM.
343	Test Runs	Make test runs with the FFM
344	Model Transfer	Transfer the technology to BWDB/FFWC or FAP 10
345	Application	Help FAP 10 in applying the FFM in real time during the monsoon of 1994.
349	Documentation	Prepare guidelines and document logic and methodology

Task 350 - FHS Update

Definition The Flood Hydrology Study (FHS) under the 1st phase of FAP - 25 was carried out based on 25 years simulation of GM (Run - 6). During this phase (FMM) the FHS results (statistical analysis) will be updated based on yet another set of 25 years run with the updated GM at FAP 25.

Objectives To produce updated statistical analysis to study impacts of selected embankment scenarios in major rivers.

Prerequisite

Results/Outputs Flood frequency and design events for major rivers.

Linkages Tasks 120, 310,

Responsibility Local Hydraulic Modelling Engineer
(Deputy Team Leader)

Time frame 2 months

Resource

Professional Resource	Man Month
Team Leader	0.25
Local Hyd. Modelling Engineer	1
Modelling Engineer	2

Sub-tasks

Code	Sub-task	Duration	Description
351	GM - FAP 25	1 day	Modify the updated GM to match the previous GM - FAP 25 (with fewer rainfall stations and NAM catchments
352	NAM - GM - FAP 25	1 week	Transfer the NAM - GM FAP 25 from SWMC and install at FAP 25 and simulate the runoff for 25 years.
353	Data base	1 week	Transfer the 25 years Database into HP UX
354	Simulation (Run)	1 week	Run the GM - FAP 25 for 25 years
355	Update FHS results	2 weeks	Make error analysis ad update statistical analyses of FHS
356	Scenario Runs	1 week	Run a few selected embankment scenarios for the recent years
357	Report	2 weeks	Prepare the updated FHS report.
356	Scenario Runs	1 week	Run a few selected embankment scenarios for the recent years
357	Report	2 weeks	Prepare the updated FHS report.

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5.6.4 Activity 400 - FMM NCRM Application

Table 5.5 Activity 400 - FMM NCRM Application

Code	Task	Description
410	Hydraulic Modelling	Acquisition, setting up, refinement and simulation of the NCRM.
420	Additional Data Acquisition	Acquisition, enhancement and quality assessment of the NCRM DEM.
430	DEM	Collection of addition data
440	Flood Mapping	Generation of flood extent, depth and duration maps
450	Flood Impact Assessment	Flood impact assessment using FMM
460	Initiate Historical Database	Computerised database of historical scenarios
470	Regional Flood Forecasting	Investigate the feasibility of using the NCR FMM for flood forecasting

Task 410 - Hydraulic Modelling

Definitions The application of the FMM on a regional levels based on the NCRM developed by the SWMC

Objectives To develop a bespoke FMM for the North Central Region and to demonstrate its application for selected scenarios.

Prerequisites SWMC Model of NCR, Tasks 240, 420

Results/Outputs Water levels at all computational nodes within the network for historical events and for selected scenarios.

Linkages Tasks 440, 450, 460, 470

Responsibility Flood Control & Drainage Engineer 1

Timeframe Duration of Project

Resources

Professional Resource	Man Month
FCD Engineer 14.0	4.0
Local FCD Engineer	10.5

410 Sub-Tasks

Code	Sub-Task	Duration (Months)	Description
411	Model Transfer	0.5	Acquire existing NCRM from SWMC and transfer to UNIX
412	Model Refinement	6.0	Make the necessary structural changes to the model to represent flood plains more appropriately
413	Calibrate	3	Re-calibrate revised model for water levels & discharges in rivers
414	Application	2.5	Set up model for selected structural interventions
419	Documentation	0.5	Prepare documentation of work done

Sub-tasks Model Refinement

Code	Sub-task	Duration (Months)	Description
4121	River System	1.0	Check network layout and revise as necessary
4122	Flood Plains	4.0	Revise representation of flood plains where appropriate
4133	Cross sections	0.5	Check existing representation of cross sections with latest surveys and refine as necessary
4124	NAM Connections	0.5	4Revise NAM catchment representation as required resulting from restructuring

Task 420 - Additional Data Acquisition

Definitions The acquisition of topographic and hydrometric data in support of the model development process.

Objectives To enhance the detail of the North Central Regional FMM

Prerequisites Cooperation with SWMC for supply of survey staff and equipment

Results/Outputs Improved reliability of hydrometric and topographic data used in model development

Linkages Task 410

Responsibility FCD Engineer 1

Timeframe Duration of Project

Resources

Professional Resource	Man Month
FCD Engineer 1	0.5
Local FCD Engineer	1.0

420 Sub-Tasks

Code	Sub-Task	Duration (Months)	Description
421	Assess existing data	0.5	Inventory and assessment of extent of existing topographic survey and hydrometric data
422	Additional Survey (1)	0.5	Prepare and supervise a programme of dry season topographic survey (embankment alignments and flood plain levels)
423	Additional Survey (2)	0.5	Prepare and supervise a programme of wet season hydrometric survey (flooding extents and river level and discharges)

Task 430 - DEM

Definitions The DEM to be used for the FMM - NCR is the DEM generated from spot heights on a 300m grid by FAP 19, (western half), and which is based on MPO square km grid for the eastern half of the region

Objectives To transfer the DEM from FAP 19, generate the DEM for the eastern half of the region. To assess the quality of the DEM's thus produced and to utilise them in the representation of the topographical features of the region..

Prerequisites Existing DEM from FAP-19

Results/Outputs Full coverage of the North Central Region with a DEM

Linkages Tasks 410, 440, 450,

Responsibility FCD Engineer 1

Timeframe Duration of Project

Resources

Professional Resource	Manmonth
FCD Engineer 1	0.5
Software Specialist	2.5
Local FCD Engineer	0.5

Sub-Tasks

Code	Sub-Task	Duration (Months)	Description
431	Acquire DEM of western sub-model	0.5	Acquire existing DEM of western sub-model
432	Quality assessment	0.5	Compare selected site survey data with corresponding areas in DEM
433	Acquire DEM for eastern sub-model	0.5	Acquire DEM of eastern sub-model area and integrate into MIKE11 model
434	Further development	0.5	Make recommendations for further development and enhancement of DEM
439	Documentation	0.5	Prepare guidelines and recommendations

Task 440 - Flood Mapping

Definitions The representation of the extents and depths of flooding in a 2-dimensional mapping format

Objectives To present samples of flood mapping for selected scenarios in the North Central Region

Prerequisites Tasks 410, 430, 230, 240, 250, 260

Results/Outputs Flood Maps

Linkages Tasks 410, 450

Responsibility FCD Engineer 1

Timeframe January - July 1994

Resources

Professional Resource	Man Month
FCD Engineer 1	0.5
Local FCD Engineer	2.5
Assistant Engineer GIS	0.5

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Sub-Tasks

Code	Sub-Task	Duration (Months)	Description
441	Network in GIS	0.5	Digitize Mike 11 network
442	Flood Surface Maps	1.0	Elaborate Mike 11 results
443	Flood Maps	0.5	Create flood maps for various scenarios
449	Documentation	0.5	Prepare guidelines

Task 450 - Flood Impact Assessment

Definitions Flood Impact maps illustrate the changes in damage/benefit resulting from flood mitigation scenarios.

Objectives To demonstrate the use of the combined GIS/Mike 11 system in providing quantitative damage/benefit analysis on a regional scale for selected scenarios.

Prerequisites Tasks 240, 250, 270, 410, 430, 440

Results/Outputs Flood Impact Maps

Linkages Task 440

Responsibility FCD Engineer 1

Timeframe January - July, 1994

Resources

Professional Resource	Man Month
FCD Engineer 1	0.5
Local FCD Engineer	2.0
Assistant Engineer GIS	0.5

450 Sub-Tasks

Code	Sub-Task	Duration	Description
451	Flood Extent Maps	0.5	Derive limits of selected flood events in terms of area, depth and duration
452	Analysis with GIS Interface	1.0	Interface with GIS data for analysis of damage/benefit with base case and selected scenarios
459	Documentation	0.5	Prepare guidelines

Task 460 - Initiate Historical Database

- Definitions** A computerised database of historic flood events incorporating various structural configurations and operational routines.
- Objectives** To provide information on the derivation of optimal operating routines for FCD structures on a regional scale.
- Prerequisites** Tasks 350, 410, 420, 430, 440, 450
- Results/Outputs** A computerised database of historical flood events with alternative mitigation scenarios.
- Linkages** Tasks 410, 440, 450
- Responsibility** FCD Engineer 1
- Timeframe** January - August, 1994
- Resources**

Professional Resource	Manmonth
FCD Engineer 1	1.0
Local FCD Engineer	2.5

Sub-Tasks

Code	Sub-Task	Duration	Description
461	Establish Base Case	0.5	Run FMM for non-intervention situation for extended period, (10-25 years)
462	Establish Modified Case	1.5	Run FMM with selected scenarios for extended period
469	Documentation	0.5	Prepare guidelines and recommendations for future database development

Task 470 - Regional Flood Forecasting

Definitions The methodology and the tool, (FFM), for regional flood forecasting will be developed in FAP-25. The application will be undertaken by BWDB, Flood Forecasting and Warning Centre

Objectives To investigate the feasibility of using the FMM for flood forecasting on a regional level.

Prerequisites The regional Flood Forecasting version of the NCRM, Task 290

Results/Outputs Real time forecast of flood plain inundation

Linkages Tasks 440, 450

Responsibility FCD Engineer 1

Timeframe May - August, 1994

Resources

Professional Resource	Manmont4h
FCD Engineer 1	0.5
Local FCD Engineer	1.0
BWDB Staff	To be allocated

Sub-Tasks

Code	Sub-Task	Duration	Description
471	Acquire Regional Model	0.25	Acquire the regional flood forecasting model from FAP-10 and convert to HP-UNIX
472	FFM	1.0	Incorporate Regional FFM methodology into Regional FF with DEM
473	Transfer	on-going	Transfer technology to BWDB staff
479	Documentation	0.25	Prepare guidelines

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5.6.5 Activity 500 - FMM TCM Application

This activity is broken down into the following tasks.

Table 5.6 Activity 500 - FMM TCM Application

Code	Task	Description
510	Hydraulic Modelling	Acquisition, setting up and simulation of the MIKE 11 TCM.
520	DEM and GIS Coverages	Acquisition, enhancement and quality assessment of DEM and GIS coverages such as crops, infrastructure, etc.
530	Data Collection	Additional Data Collection
540	Flood Mapping	Generation of flood extent, depth and duration maps
550	Flood Impact Assessment	Flood impact assessment using FMM
560	Structure Operation	Application of the FMM Structure Operation Feature



Task 510 - Hydraulic Modelling

- Definitions** The application of FMM on compartment level is based on the Tangail Compartment Model (TCM) developed at FAP 20. The TCM includes the NAM -Hydrological Module and the HD - Hydrodynamic Module.
- Objectives** To make TCM operational at FAP 25 and to produce output required for FMM application.
- Prerequisites** Transfer of existing model and data from CPP-office, Tangail.
- Results/Outputs** Water levels at all computational nodes of the TCM for selected historical flood events and for selected scenarios.
- Linkages** Tasks 120, 240
- Responsibility** FCD Engineer II
- Time frame** Duration of the Project
- Resource**

Professional resource	Manmonth
FCD Engineer II	6.0
Modelling Engineer II	12.0
Short term expert	1.0

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510 Sub-tasks

Code	Sub-task	Duration (Month)	Description
511	Model Transfer	0.5	Transfer the TCM including data from CPP and install at FAP 25 Computer (Workstation)
512	Simulation	1.0	Simulate Historical Flood events (1987, 1988, 1991) and ensure that the results are the same as those of CPP.
513	Model Refinement	12	Review model on existing schematization; make necessary extensions and calibrate/ verify for 1991 and 1992
514	'With-project' scenario	1.0	Simulate impacts of 'With-project' situation for 1987, 1988 and 1991

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Model Refinement Sub-task

Code	Sub-task	Duration (Month)	Description
5131	River system	1.0	Check network layout and add channels necessary for refinement
5132	Flood plains	2.0	Check representation of flood plains, adapt/refine where necessary
5133	Cross sections	2.0	Check existing cross-sections with newly surveyed, correct, add
5134	NAM connections	2.0	Due to more detailed schematization, catchments can be divided in smaller ones
5135	Boundary conditions	2.0	For more accurate results the location / type of the boundary conditions must be reviewed and new locations may be added
5136	Calibration/ verification	3.0	The new detailed model needs to be calibrated/ verified for the years 1991 and 1992.

Task 520 - DEM and GIS Coverages

Definitions The Digital Elevation Model (DEM) to be used for FMM - TCM is the DEM generated from the spot heights on a 40 metre grid by FAP 19.

Objective To transfer the DEM from FAP 19, install it in the FAP 25 computer, incorporate more detailed elevation data and major structures (e.g. embankments) and assess its usefulness.

Prerequisites Availability of the DEM at FAP 19 and their cooperation in transferring the data.

Results/Output DEM for the Tangail Compartment

Linkages Tasks 120, 510, 540

Responsibility Software specialist

Time frame Duration of the project

Resources

Professional Resource	Man Month
Software specialist	0.52
Modelling Eng. II	1.0
Assistant Engineer (GIS)	1.0

Sub-tasks

Code	Sub-task	Duration	Description
521	DEM - Transfer	0.25	To transfer the DEM from FAP 19 to FAP 25 Computer
522	Refinement	on going	Verification of embankment locations and conditions, flood plain inundation and incorporation of channel cross-sections
523	'With-project' situation	0.5	Incorporate the 'With-project' situation in the DEM

Task 530 - Data Collection

- Definitions** The data will mainly be collected from FAP 20 and consists of updated cross-section and elevation data and water level and discharge observations.
- Objectives** Validate the data and use it for model improvement and calibration/verification.
- Prerequisites** Cooperation of FAP 20 and FAP 3
- Results/Outputs** Reliable data
- Linkages** Tasks 120, 510
- Responsibility** FCD Engineer II
- Time frame** Duration of the Project

Resource

Professional resource	Manmonth
FCD Engineer II Modelling	1.0
Engineer II	2.0
Short term expert	0.5

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Task 540 - Flood Mapping

Definition The flood plain inundation maps will be derived for the existing conditions and the 'With-project' scenario by superimposing the water surface derived from the TCM upon the Tangail DEM.

Objectives To demonstrate the application of the RMM - Module on compartment level.

Assumptions

Results/Output Flood Maps

Linkages Tasks 220, 510, 520

Responsibility FCD Engineer II

Timeframe January - July 1994

Resources

Professional Resource	Man Month
FCD Engineer II	0.5
Modelling Engineer II	2.0
Assistant Engineer (GIS)	0.5

Sub-tasks

Code	Sub-task	Duration	Description
541	Network in GIS	1.0	Digitize MIKE 11 network
542	Flood surface maps	0.5	Elaborate MIKE 11 results
543	Flood maps	0.5	Create flood maps
544	Documentation	0.5	Prepare guidelines

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Task 550 - Flood Impact Assessment

Definition Flood impact maps show the change in damages/benefits for before and after scenarios.

Objectives To demonstrate the application of the PDM - Module on compartment level.

Assumptions

Results/Output Flood Impact Maps

Linkages Tasks 230, 510, 520

Responsibility FCD Engineer II

Timeframe January - July 1994

Resources

Professional Resource	Man Month
FCD Engineer II	0.5
Modelling Engineer II	2.0
Assistant Engineer (GIS)	0.5

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Sub-tasks

Code	Sub-task	Duration	Description
551	Flood impact maps	1.0	Create flood level impact maps
552	Investigation	1.0	Investigate on damage/benefit

Task 560 - Structure Operation

Definitions The application of the Structure Operation Module (SOM) on compartment level is based on the refined Tangail Compartment Model (TCM).

Objectives To make TCM operational as a Structure Operation Module at FAP 25 and to produce output required for FMM application.

Prerequisites

Results/Outputs On-line flood management tool on the effects of operation of control structures

Linkages Tasks 120, 240, 510

Responsibility FCD Engineer II

Time frame April - August 1994

Resource

Professional resource	Man Month
FCD Engineer II	3.0
Modelling Engineer II	5.0
Short term expert	0.5

Sub-tasks

Code	Sub-task	Duration (Month)	Description
561	Model modification	1.0	Include newly developed structure options and test
562	Structure operation rules	2.0	Apply structure operation rules to generate a tailored pilot FMM
563	Strategies	2.0	Run the model with various management/operation strategies in order to evaluate its usefulness

5.6.6 Activity 600 - Workshops and Trainings

During the FMM study it is planned to organize three workshops for the model users, relevant GOB authorities, SWMC and FAP consultants. The workshops will be used as effective fora for disseminating knowledge as well as obtaining feedback on proposed concept, methodology and application of FMM. The three workshops are identified as three tasks as shown below.

Table 5.7 Activity 600 - Workshops and Training

Code	Task	Description
610	Workshop I	First workshop to be held at the end of the system analysis phase.
620	Workshop II	Second workshop at the end of the FMM development phase.
630	Workshop III	Third and final workshop at the end of the FMM application phase.
640	Training	Consolidated training course on Flood Modelling and Management.

Trainings

The local staff working at the project will be trained through on-the-job training during the project period. As agreed with the chief Engineer - Hydrology, three to four engineers from the FF&WC of BWDB will work in FAP25 during October - December 1993. They will learn the FMM technology in order to enable them to apply it to real-time flood forecasting. Arrangements are also being discussed so that expatriate consultants will be able to work at FAP 25 during the bridging period of FAP 10 (October - December, 1993).

In addition to the above, based on the recommendations from the First Workshop on FPCO's request it is planned to organize a consolidated training on flood modelling and management for the senior staff of FPCO and BWDB - Hydrology. The training course will be divided into three modules:

- Module I : (1 week) Data Management and Hydrological Analysis
- Module II : (3 weeks) Mathematical Modelling
- Module III : (2 weeks) Flood Management Model

Three weeks of the training will be conducted at DHI, Denmark and three weeks at Dhaka. This training program is a separate activity under DANIDA's scholarship scheme.

Task 610 - First Workshop

Definitions The concepts and logic of FMM will be discussed during the first workshop the be organized at the end of inception phase

Objectives To create awareness of FMM and obtain feedback from FMM users.

Prerequisites Task 710.

Results/outputs Recommendations to be incorporated in the Project planning/Final Inception Report.

Linkages Activity 200, Tasks 110, 120, 710

Responsibility Team Leader

Timeframe Before the first 4 months

Resources

Professional Resource	Man Month
Team Leader	0.5
Comp. Hyd. Engr.	0.25
Software Specialist	0.1
Local Professionals	as
Short term expert	appropriate

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Sub-tasks

Code	Sub-task	Duration	Description
611	Planning		Plan program, identify participants and resource persons, invitations, liaison.
612	Organization	3 days	Organize the workshop
613	Documentation	1 week	Reporting the Recommendations and incorporation in the Inception Report.

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Task 620 - Second Workshop

Definitions The Second Workshop will be organized at the end of FMM development period

Objectives To present the FMM to prospective users and to obtain feed back

Prerequisites Activity 200

Results/Outputs Finalization of Interim Report - 1

Linkages Tasks 120, 610, Activities 200,

Responsibility Team Leader

Timeframe Before month 11.

Resources

Professional Resource	Man Month
Team Leader	0.25
Comp. Hyd.Engr.	0.5
Software Specialist(exp.)	0.5
Software Specialist (loc.)	as appropriate
Modelling Engr.- 1	as appropriate
FCD Engr.	as appropriate

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Sub-tasks

Code	Sub-Tasks	Duration	Description
621	Planning		Plan program, identify participants and resource persons, invitations, liaison.
622	Organization	2 days	Organize the workshop
623	Documentation	3 days	Reporting the recommendations, finalizing the First Interim Report

Task 630 - Third Workshop

Definitions The Third Workshop will be conducted towards the end of the project. The full FMM and its applications will be demonstrated. Need for further development will be identified.

Objectives To demonstrate FMM applications, technology transfer

Prerequisites All activities should be completed before the Third Workshop.

Results/ Outputs Final Report

Linkages Activities 200, 300, 400, 500, 700.

Responsibility Team Leader

Timeframe Before the end of the Project

Resources

Professional Resources	Man Month
Team Leader	0.25
Comp. Hyd. Engr.	0.5
FCD Engr. - I	0.5
Local prof. staff	as appropriate

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Sub-tasks

Code	Sub-Task	Duration	Description
631	Planning		Plan program, identify participants and resource persons, invitations, liaison.
632	Organization	2 days	Organize the workshop
633	Documentation	1 week	Reporting the recommendations, finalizing the Project Report.

5.6.7 Activity 700 - Reporting

The project will produce the following reports which are assigned with tasks as presented in Table 5.8. Respective Draft reports will be produced one month prior to the final report.

Table 5.8 Activity 700 - Reporting

Code	Task	Description
710	Inception Report	Layout detailed plans, concepts of FMM.
720	Interim Report I	Report on FMM development
730	Interim Report II	Report on FMM Application
740	Final Report	Final Project report
750	FMM Manual	Documentation of FMM User's Guide and Reference Manual including training material.

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GLOSSARY

Khal	a natural minor channel
Upazila	sub-district
Zila	district
Beel	a low-lying area with permanent drainage congestion
Compartment	an area in which effective water management, particularly through controlled flooding and controlled drainage, is made possible through structural and institutional arrangements. A compartment can be subdivided into sub-compartments.



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APPENDIX A - TERMS OF REFERENCE

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BANGLADESH
ACTION PLAN FOR FLOOD CONTROL



FLOOD MODELLING AND MANAGEMENT

TERMS OF REFERENCE
for
Flood Management Model (FMM)

FLOOD PLAN COORDINATION ORGANIZATION
MINISTRY OF IRRIGATION, WATER DEVELOPMENT
AND FLOOD CONTROL

Dhaka, May 1992



1. INTRODUCTION

The disastrous floods of 1987 and 1988 prompted the Government of Bangladesh to undertake a comprehensive review of its flood policy. In June 1989, the Government of Bangladesh requested the World Bank to coordinate a five year Action Plan (1990-95), based on earlier studies, as the first of several stages in the Government's long-term flood control program.

In its November 1989 report, the World Bank presented an Action Plan which addresses high priority problems and follows a staged approach which:

- concentrates in the first years on regional studies of flood control and drainage potential and supporting activities in order to identify feasible projects for implementation later in this and in subsequent Action Plans;
- focuses on flood control from the Brahmaputra and Ganges (with the downstream problems of the Padma and Lower Meghna deferred until the effects of upstream embankments on river morphology are evaluated).

The Action Plan would be carried out in a coordinated manner and in parallel with agricultural and other rural development activities and a program of non-structural measures, including flood warning and flood preparedness.

The Action Plan was discussed among donors at a meeting in London in December 1989. During this meeting, donors from Denmark, France and the United Kingdom expressed their interest in participating in the execution of the Action Plan Component No 25: "Flood Modelling and Management". In March 1990 also the Netherlands joined the group of interested donors in designating a Dutch expert as member of the Coordination Advisory Team (CAT).

As agreed at the meeting, the Danish Ministry of Foreign Affairs (DANIDA) would play the leading role in this project. DANIDA is presently financing a major model development effort in Bangladesh (the Surface Water Simulation Modelling Programme - SWSMP).

The ongoing SWSMP activities are carried out in the Surface Water Modelling Center (SWMC) of the Water Resources Planning Organisation (WARPO) under the Ministry of Irrigation, Water Development and Flood Control (MIWDFC).

FAP 25 - Flood Modelling and Management - consists of three components:

- i) A Coordination Advisory Team (CAT);
- ii) Flood Hydrology Study (FHS);
- iii) Flood Management Models (FMM).

The first two of these project components, CAT and FHS, are ongoing, under the responsibility of the Resident Model Coordinator/Team Leader. Provisional Terms of Reference (TOR) of FMM have been approved in June 1990. The present document is the final TOR of FMM; it has been prepared on the basis of extensive discussions with relevant GOB authorities and FAP study consultants with a view to defining end-user requirements and expectations.

The Flood Plan Coordination Organization (FPCO) under the MIWDFC will be the Implementing Agency of the FMM component. DANIDA will be the coordinating Donor Agency on behalf of the contributing donors, Denmark, France and the Netherlands. The Dutch support to the project will be provided through FAP 20 - the Compartmentalization Pilot Project.

2. BACKGROUND

Bangladesh is a flat delta at the confluence of three major river systems of the world: the Ganges, the Brahmaputra and the Meghna. The total drainage area of these river systems is more than 1.55 million square kilometers of which about 7.5% lies within Bangladesh. The stream flow originates in upstream catchments in India, Nepal, Bhutan and China (Tibet). The average flood peak of the combined Ganges-Brahmaputra in the Padma River is 110,000 m³/s. The average rainfall within Bangladesh varies from 1,100 mm in the west to 5,700 mm in the north east. About 75% of the rainfall is concentrated in the period from June to September. Consequently Bangladesh has too much water during the wet season from June to September and too little during the dry season from November to May.

With more than half the country under the 12.5m contour some 30% of the cultivable area of Bangladesh is flooded in a normal year. An estimated 50% is vulnerable to either monsoon or tidal floods. Only some 20% of the vulnerable area is protected.

Flooding in Bangladesh is commonly caused by a combination of several factors such as:

- monsoon flows generated from rainfall occurring in a short span of time in the upstream catchment and consequent overbank spilling of the main rivers; for some of the rivers, with a steep catchment, this may result in flash floods;
- runoff generated by heavy local precipitation and that sometimes cannot drain out due to high stage in the outfall rivers, and
- cyclone tidal bores or storm surges in the Bay of Bengal predominant during pre- and postmonsoon periods, i.e. April to May and October to November.

These factors, individually or in combination, may influence the occurrence and magnitude of flooding.

The 1987 and 1988 floods in Bangladesh are two of the most severe floods on record.



Widespread damage was caused to crops, roads, railroads, cities and towns, and more than three thousand people lost their lives. These floods caused a major setback to the country's economy, in part because of heavy expenditures by the Government in its prompt and effective relief efforts and in part by the disruption of economic activities.

It is worthwhile noting that these two floods had very different physical origin. The most serious of the 1987 floods resulted from very heavy rainfall in the period July to September over northwest Bangladesh and the area of West Bengal immediately to the north. These local rainfall generated floods were further aggravated by the highest flood peak ever recorded on the Ganges, an exceptionally high flood on the Teesta, and, despite a Brahmaputra flood only slightly above average, breaches in the Brahmaputra right embankment. The 1988 floods were generated by intensive rainfall in the upper catchments resulting in high cross border flow, while local rainfall was near normal. The flood peak of the Brahmaputra was the highest ever recorded. The flood peak of the Ganges was also high, but most significantly the two peaks coincided with devastating effects on the Padma downstream of the Brahmaputra/Ganges confluence. Adding to the flood congestion in the Lower Meghna were an exceptionally high flood on the Meghna.

3. THE SURFACE WATER MODELLING CENTRE

The Surface Water Simulation Modelling Programme (SWSMP) was established because of the widespread recognition that the effective control and utilisation of water resources in Bangladesh is vital to the economic and social development of the country. Mathematical models of the complex river system are in this respect indispensable tools for an integrated approach to planning and design. The first phase of SWSMP commenced in 1986, financed by United Nations Development Programme (UNDP) and executed by the World Bank. The ongoing second phase (SWSMP-II) is running from December 1989 through November 1993 and is financed by DANIDA. Danish Hydraulic Institute (DHI) has been the Consultant since project start in 1986.

The SWSMP aims at developing a suite of mathematical river models (the SWMC models) at two different scales based on the generalised MIKE 11 software package. The models are:

- The **General Model(GM)** covering the entire area of Bangladesh with the exception of Chittagong and the Hill Tracts. It includes the main rivers of the country, totalling 2,410km in length. The GM serves as a planning and design tool for large scale flood control, drainage and irrigation projects. It is also the basis for an upgrading of flood forecasting facilities. The GM also provides boundary conditions for:
- **Six Regional Models** including:
 - * South East Regional Model(**SERM**) bounded by Meghna to the west, the Bhairab Bazar to Comilla railway line to the north

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- * South Central Regional Model(SCRM) - the Padma to the north, the Lower Meghna to the east and the Gorai/Madhumati to the west.
 - * South West Regional Model(SWRM) bounded by the Ganges to the north, and Gorai/Madhumati to the east.
 - * North West Regional Model(NWRM) bounded by the Jamuna to the east and the Ganges to the south.
 - * The North Central Regional Model(NCRM) bounded by Old Brahmaputra to the north and northeast, Jamuna to the west, Padma to the south and Meghna in the east.
 - * North East Regional Model(NERM) covering the Upper Meghna basin down to Bhairab Bazar

The regional models provide a finer resolution of the regional river and drainage network than does the GM. They are used as planning and design tool within the particular region allowing to describe effects of embankments along minor rivers, polders, regulators, pump stations, dredging etc; they may also be the basis for accurate flood forecasting at a regional scale and finally, they may provide boundary conditions for local, subregional models which may be required for detailed analysis of specific projects.

Each of the models contains a rainfall-runoff component to simulate the catchment runoff and a hydrodynamic component with emphasis on simulating water levels and flows in rivers and khals. Two additional modules enhance the applicability of the MIKE 11 software package, namely i) a salinity module for simulation of salinity intrusion in rivers and ii) a sediment transport module which allows simulation of cohesive and non-cohesive sediment transport rates. Tailored sediment transport models are being developed for each of the regional models as well as the GM. Tailored salinity models are being developed for the GM, the SCRM and the SWRM.

The model development takes place in three stages from pilot stage through full model stage to verified stage, applicable in broad terms to planning and prefeasibility studies; feasibility studies and outline design, and detailed design respectively.

4. FLOOD MANAGEMENT MODEL (FMM)

4.1 Justification

In considering the need of the Flood Management Model (FMM) it is important to review the current work of the Surface Water Modelling Centre and the experience gained by the Regional Consultants during the early phases of the Flood Action Plan.

The Surface Water Modelling Centre is essentially developing hydrodynamic models for Bangladesh and training local personnel in their use. The work was initiated long before

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the Flood Action Plan and was originally aimed at the provision of models which would have the capability of investigating effects of development activities, additionally low flow irrigation and salinity intrusion problems.

The commencement of the Flood Action Plan in 1989 introduced a new dimension into the modelling requirements including the need to be able to study major flood plain flows and storage. The Flood Action Plan has also highlighted the need for morphological modelling and analysis. Staffing at the Surface Water Modelling Centre was strengthened in order to cope with the additional workload.

The models from the SWMC are essentially planning tools; they are (being) verified on existing conditions and then used to evaluate the effects of engineering work. The output from the models gives the variation of water levels and flows throughout the model area with time, considering also the storage characteristics of the flood plains. The models do not indicate directly detailed areas and depths of inundation. Such information is very important for proper flood management the aim of which would be to minimize flood damage, including loss of life, property, crops and other consequential effects resulting from various types of river floods or direct rainfall.

One of the very central elements in the Flood Action Plan is "compartmentalisation" allowing controlled flooding and drainage within and between compartments and between compartments, main rivers and drainage channels. The flows may be through non-gated, throttling structures and/or gated structures on the rim of the subcompartments/compartment(s). Identification of overall water management strategies for compartments and development of (simple) operational rules are essential for successful implementation of compartments on a large scale.

The Flood Management Model study is addressing these needs of more detailed information on flood plain inundations and development of operational guidelines for flood control structures and schemes in general and for compartment(s) in particular.

The target group of the FMM development includes:

- flood management decision makers;
- operators of FCD schemes in general and of compartments in particular;
- flood forecasting authorities;
- planners and designers of FCD schemes and other infrastructure developments (roads, highways, railways), which may have an impact on flooding and drainage conditions;
- demonstration centres for flood management awareness
- inland water transport authorities;

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- universities (research, education and training)

The exact institutional framework for continued development, maintenance and application of FMM beyond this study still has to be elaborated. The yet to start FAP 26 - Institutional Development Programme - will have to address this issue. Clearly the eventual home of FMM for on-line operation and management will be an emergency flood control room (probably BWDB) in conjunction with the Flood Forecasting and Warning Centre. BWDB will also be a major user for project preparation and design purposes, while the SWMC under WARPO should have the responsibility of continued development and maintenance of the FMM and application for macro-level planning considering the comprehensive capacity building effort done under SWSMP-II. Other potential users specified under the target group above are expected to have easy access to these FMM centres.

4.2 Concepts and Applications

In basic terms FMM is a user friendly graphics based tool designed to assist decision makers in the management of floods.

The Flood Management Model(FMM) for Bangladesh may be seen as a hierarchy/system of models, which could be used on different scales:

- national and regional scale, building directly on the SWMC models, and
- subregional and compartment scale being developed ad-hoc as and when required and based on the MIKE 11 software package

Considering the ultimate use of FMM and the likely institutional framework Table 4.1 summarizes various characteristics of the FMM including the model operation level, potential users, drainage features which may typically be accommodated at the various scales and, finally, main types of application.

In addressing the needs the FMM should include the following features:

- linkage of the present MIKE 11 based SWMC models to a digital elevation model (DEM) to facilitate rapid interpretation of water levels in terms of flooded areas and depths;
- more versatile representation of flood control structures;
- enhanced graphics and more user friendly "front-end";
- the capability of usage off-line to determine flood management strategies and on-line to assist flood forecasting;

Table 4.1: Flood Management Model - Basic Characteristics and Usage.

	FMM Basis		
	General Model	Regional/sub-regional model	Local Model
Possible Model Operation Level	Central level	Central or Regional level	Central, Regional or District Level
Potential Model Users	BWDB, WARPO, RRI, DoE, BIWTA, BUET, consultants	BWDB, WARPO, RRI, DoE, RHD, MoA, BIWTA, BUET, consultants	BWDB, FPCO, LGEB, MoA, Project Committees, BUET, consultants, NGO's
Typical Drainage Features in the Model NOTE! A controlled hydrological unit means that structures on the rim of the unit can be represented in the model	*Major river drainage network *Cluster of compartments(5-10) as controlled hydrologic units *Compartments (10,000ha) as single, uncontrolled hydrological units	*Regional river drainage network *Compartments as controlled hydrological units *Subcompartments (1,000 -2,500 ha) as uncontrolled hydrological units	*Compartment with major drainage network *Subcompartments (1,000 -2,500 ha) as controlled hydrological units *Subcompartment units(100-250ha) as uncontrolled hydrological units
Main Types of Model Application	Off-line: Development of flood management strategies. Planning, design, training and demonstration. On-line: Real-time flood forecasting and management.	Off-line: As for GM On-line: Real-time flood forecasting and management, but only on central level	Off-line: As for the GM On-line: Flood management, but applications not likely yet

It can be seen that the FMM includes modifications to the basic capabilities of of MIKE 11 and also the provision of software to link MIKE 11 to DEM. The proposed FMM

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study, in addition to the development of the FMM itself, would include building and demonstrating the usage of three pilot FMM models (see section 6.2) tailored to specific areas and specific types of problems.

Bespoke FMM's of specific areas can be envisaged at various levels: nationwide, regional, sub-regional and compartmental. At each level their usage may include development of flood management strategies or usage for actual flood forecasting and management. Additional usage include training in flood management awareness and for demonstration of benefits/disbenefits of proposed FCD measures and consequences of uncontrolled public action (e.g. embankment cuts) to local level beneficiaries/disbeneficiaries of such schemes and actions.

Although the FMMs are essentially management tools, they will have clear benefits for general water resources planning and development and other FAP activities, for example:

- Planning (National Coarse Model): updated regional or consolidated plans to examine effects of interactions of various regional/project implementation programmes (eg comparing effects of advancing or delaying main river embankment strengthening, alternative new embankments).
- Project Preparation (Pilot Regional Model): assisting feasibility level design of FCD measures through simulation of various operating modes for selected hydrological events.


5. RELATION TO SWMC AND OTHER FAP STUDIES

The time schedules of the various FAP studies in relation to the FMM component of FAP 25 are such that FAP 10 and 20 are likely to have major benefit from the development under FAP 25.

The regional FAP studies may have some benefit from possible DEM developments and preliminary developments of the interfacing with MIKE 11. Generally and with their present scope and time schedule these FAPs will, however, mostly have to rely on the SWMC models in their actual stage of development. Only after 1994 will the FMM development as proposed in these Terms of Reference substantially benefit a broader group of potential end-users.

For the development of FMM FAP 25 will establish coordination/ liaison links with relevant GOB agencies and draw on the relevant findings of FAP components as may be available at the time. In particular, the Consultant will work in close cooperation with:

- SWMC as responsible for development of the General and Regional Models, for possible additional primary data collection and for demonstration and training purposes;

- 
- FAP 19 - Geographic Information System, developing Digital Elevation Models for the General Model, the North Central Regional Model and the Tangail Compartment model, testing interfacing techniques of DEM with MIKE 11 and developing a GIS database for the Tangail area.
 - FAP 10 - Flood Forecasting and Warning, for testing the pilot FMM for the North Central region and the coarse FMM based on the General Model for inundation forecasting.
 - FAP 20 - Compartmentalization Pilot Project, for developing and testing the pilot FMM for the Tangail compartment.

SWMC will provide FAP 25, free of charge except for direct cost associated with model transfer, updated versions of the General Model (verified stage) and the North Central Regional Model (pilot stage from the start, full stage by December 1992 and verified stage by April 1993) and including model input data available with the SWMC (topography, river cross-sections and hydrology). It is noted that SWMC during 1991-93 is carrying out a comprehensive primary data collection programme (through subcontracted survey teams and BWDB Hydrology) in the NC region in addition to the routine programme of BWDB Hydrology. Further primary data collection (cross sections and hydrology) in addition hereto for possible detailing of the NCRM in 1-2 selected areas would be agreed upon between FAP 25 and SWMC, financed by FAP 25, and carried out by SWMC under their general data collection programme. Field monitoring will be carried out by FAP 25 staff.

FAP 19 will provide a geographic information system(GIS) to assist in planning and managing geographic information for the FAP. A series of pilot studies and GIS application projects have been implemented. Of particular relevance for the FMM development is the pilot study on digital elevation models (DEM) and spatial interfacing with output from the SWMC models. This pilot study is expected to run from late 1991 until mid or late 1992. The study will provide:

- description of alternative data capture and digital terrain modelling methods
- recommendations on suitable methods for establishing digital elevation data as model input; for general, regional and local models
- procedural guidelines on converting MIKE 11 output to maps of flood extent and depth through interfacing with DEM; for general, regional and local models
- prototype flood hazard maps for regional/local scale

Another potentially important study of FAP 19 is related to the use of GIS as a mapping and analytical tool for Environmental Impact Assessment. The linkage/superimposing of DEM/MIKE 11 produced inundation maps with GIS (comprising different overlays with information on cropping pattern, cropping values, infrastructure and flood damage cost

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functions) may lead towards a more comprehensive and sophisticated decision support system at later stages. Such comprehensive linkage is outside the scope of FAP 25's TOR. However, it is proposed within the present project to demonstrate, on a pilot scale, the potential of such linkages for the compartment FMM.

From these pilot studies and application projects FAP 19 will provide FAP 25, free of charge except for direct costs associated with data transfer:

- A coarse DEM for Bangladesh based on MPO 1 km grid and established under the ongoing DEM pilot project of FAP 19.
- A DEM for the North Central region based on BWDB 4":1 mile maps (spot heights) and updated with latest available information from FAP 18. Within their present resources FAP 19 will only be able to develop the DEM for the western part of the NC region (corresponding to the western submodel of the NCRM). Financial resources for developing the eastern submodel will be made available from FAP 25. The actual work may be done by SPARSSO under the guidance of FAP 19.
- A detailed DEM for the Tangail compartment based on BWDB 4":1 mile maps and updated with the new 1:10,000 maps (with 0.25 m contour intervals) to become available from FAP 18 by June 1992.
- The GIS database being developed for the Tangail compartment.

It is stressed that the above transfers relate to the particular databases being established, while FAP 25 will have to acquire its own general GIS/DEM software.

FAP 10 will not provide direct input to FAP 25 but will be consulted in connection with the initial system analysis to ensure that the FMM development are fully compatible with the GM-FF (the modified General Model being used for Flood Forecasting) and any regional flood forecasting models being applied, especially the real-time procedures applied in the FF&WC. FAP 10 will be requested to test, with support from FAP 25, the MIKE 11-DEM interfacing for inundation forecasting being developed in the initial stage of the FMM study.

FAP 20 will develop and test the FMM for the Tangail compartment in close cooperation with FAP 25 and under the TOR outlined in Chapter 7. FAP 20 will be involved in the initial system analysis for the FMM and participate in the proposed workshops. FAP 20 will make available all field data being collected for developing the present simple compartment model and undertake additional field data collection (topographic survey, cross section survey and hydrological data) as may be required for the FMM development for the Tangail compartment. FAP 20 will divide its work between the FAP 20 office in Tangail and the FAP 25 in Dhaka as it is most suitable and agreed upon by the two team leaders. Computer facilities in Tangail, accommodation and transport of the FAP 20 staff will be provided directly by FAP 20.



6. SCOPE OF WORK

6.1 Objective

The overall long term objective is to achieve an on-line mathematical model linked to the flood forecasting model of FAP 10, which would provide information to assist in the management and control of floods in real-time with parallel simulation of a range of possible scenarios. The model would indicate river water levels, areas and depths of inundation and ideally the impacts in terms of potential crop losses, displacees, infrastructural disruption etc., all in clear graphical or tabular form which could be easily and rapidly assimilated. The information would be used for disaster preparedness/management as well as for the operation of flood control measures.

Clearly such a model would be a highly ambitious undertaking at this stage, particularly as FAP is still in its infancy as regards comprehensive and integrated plans for flood control and drainage, full topographic and morphological data, and agricultural and demographic information. It is thought that the likely uses of the FMM will prove in time to be so diverse that the development of the model will continue for many years. The speed of development depends on numerous factors including:

- perceived needs and awareness of the benefits of a FMM among potential users
- quality of the data providing the basis for the development of new modules of the FMM
- development in computer technology
- institutional capability to maintain and apply a FMM

On this background the development of FMM should take place in clearly defined phases. The present TOR cover a two-year period at the end of which possible recommendations for further development may be brought forward with due consideration to the above mentioned factors.

6.2 Output

A limited objective project has been formulated in which the long term aim can be tried out on a pilot scale at different levels. The output of the project will be:

- **National Level** A coarse FMM using the existing General Model for off-line prediction of flood plain inundation for various scenarios of river floods, rainfall, and embankment and structure configurations. Linked to FAP 10's flood forecasting model, it may be used for inundation forecasting (but at coarse level). This would be the first pilot step in on-line management.

- **Regional Level A** detailed pilot FMM for the North Central Region using the verified NCRM of the SWMC (eventually allowing for some additional details in selected areas) for prediction of flood plain inundations as for the General Model above. However, the difference would be in the detail; extent and depths of inundation would be less coarse, ideally giving more accurate forecasts at Upazila level; and simulating different configurations and operational modes for compartments and polders. The North Central is selected because of the recently completed topographic surveys and because full river embankment options are still open.
- **Compartment (micro) Level** a detailed FMM at micro level using the existing model for Tangail (FAP 20) for predicting inundation depths and durations for various management strategies, but with greater accuracy. It would test out the effects of operation of hydraulic structures and, as a pilot for a more comprehensive management model, would introduce land use and demographic information by demonstrating possible coupling with GIS (as being developed by FAP 19).

At the end of the two-year programme of development, application and demonstration, the project will have produced, in addition to the above outputs, software for application to other regions including manuals/guidelines. A decision would then be taken on possible further development, including on-line management models. Through a series of workshops during the study period increased awareness would have been created on the potential and benefits to be achieved from the FMM among possible end users in the GOB system and beneficiaries' organisations at regional or local level. Finally, recommendations on institutional responsibility for applying the FMM, and hence the need for training programmes to be part of possible next phase(s) will be prepared.

In carrying out the FMM study, the Consultant is assumed to use existing topographic and hydrological data and models as detailed in Chapter 5. However, a small provision is kept for primary data collection during 1992/93 dry season and 1993 monsoon season, depending on the need of detailing the NCRM in one or two areas (e.g Jamalpur, area between Dhaleswari and Bangsi rivers or Greater Dhaka).

7. ACTIVITIES (TOR for Consultants)

The development of FMM will be carried out in two stages:

Stage 1 - Development Phase:

Undertaking the necessary enhancements to the MIKE 11 modelling system including the provision of an interface with DEM software.

Stage 2 - Application and Demonstration Phase:

Setting up and demonstrating bespoke (tailored) models at compartment, regional and national level. Initial emphasis will be on compartment level.

The tailored FMM for the Tangail compartment goes beyond the present scope of modelling in FAP 20 and may include high resolution DEM and water control structures at subcompartment/ compartment rims. It may be used to study broad water management strategies for subcompartments, individual compartments as well as between-compartment operation strategies under various hydrological and hydraulic conditions. This may lead to the formulation of a set of practical rules for actual operation of subcompartment/compartment inlet and outlet regulators.

Activities to be undertaken include, but would not necessarily be limited to:

Stage 1 - Development Phase:

a) System Analysis:

- undertake a system analysis to define the basic concepts and logics of FMM, including general requirements, detailed specification of individual modules/routines and their interfacing;
- conduct a workshop before the end of month three for relevant GOB authorities and users of SWMC models with the purpose of demonstrating the models and discuss the result of the system analysis before FMM development is initiated;

b) Interfacing MIKE 11 and DEM:

- decide, in close consultation with FPCO, SWMC and FAP 19, and based on the findings of the FAP 19 pilot study, on most suitable DEM software, and on suitable interfacing techniques with MIKE 11;
- make recommendations on and decide in consultation with FPCO and SWMC on FMM operating system (DOS or UNIX);
- acquire a suitable DEM software package and make arrangements for an agreement on the combined use of a MIKE11 - DEM package;
- develop MIKE 11 - DEM interface to:
 - * process topographical flood plain and rainfall-runoff catchment data
 - * calculate intersection between MIKE11 output (three-dimensional water surface) and three-dimensional ground surface

c) Enhancement of Graphics and Other Postprocessing Facilities:

- develop, in consultation with FAP 19 and considering the possible benefits which may be achieved from GIS, graphic module(s), including zoom and pan facilities,

to enable easy overview as well as detailed scanning so as to display:

- * time series of rainfall, water level and discharges
 - * two- and three-dimensional images of land and water surfaces (flood characteristic maps)
 - * tables showing inundation depths
 - * line drawings showing position of gate controls and pumps, and their mode of operations
- statistical package for analysis of model performance and output;
- d) Modifications and New Add-on Routines in Core Modules of MIKE 11:
- establishment of feedback mechanism between hydrodynamic and rainfall-runoff module to allow the description of flood plain flooding and drainage to interact with sub-surface storage;
 - improvement of structure operation routines to suit the specific purposes laid out by other FAP projects;
 - tailoring of the existing embankment breaches routine, which simulates the dynamic expansion of embankment breaches, to comply with the normal characteristics found for such breach development in Bangladesh;
 - development of logical rules and optimization routines, which can relate gate openings or pump operations to hydrological and hydraulic conditions elsewhere in the system and determine appropriate sequence and timing of operations;
 - present the general FMM developments at a workshop for GOB authorities and other potential FMM users with a view to identifying possible modifications;

e) Additional Field Data Collection

- identification, during the inception stage and in consultation with FPCO, the need of detailing the pilot FMM for the North Central region in 1-2 selected areas;
- definition, in cooperation with the SWMC, of the need of additional primary field data collection in such areas and arranging for such surveys with SWMC;

Stage 2 - Application and Demonstration Phase:

a) Finalization of General FMM Development

- finalize the general FMM development and prepare FMM Scientific Documentation and User's Guide.

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b) Bespoke Compartment FMM:

- development of (by FAP 20 in close cooperation with FAP 25) a pilot FMM for the Tangail compartment, in which the existing and proposed main drainage features of the compartment will be represented as well as existing and proposed inlet and outlet regulators on subcompartment/compartment rims;
- use the compartment FMM to evaluate and demonstrate management strategies and simple operation rules for the compartment;
- consider, in cooperation with FAP 19 and FAP20, the feasibility and possible benefits of future interfacing/ integration of MIKE 11 and GIS (different overlays providing information on cropping pattern, cropping values, infrastructure and flood damage cost functions) to determine flood damage potential of particular floods;
- exemplify, on a pilot scale, such possible linkages to GIS as found appropriate;

c) Bespoke Regional FMM:

- build a regional FMM for the North Central region and carry out FMM demonstration runs showing the effects of different structural arrangements and operations under different flooding conditions and produce flood hazard maps for various historic floods and return periods;
- initiate, on this basis, the establishment of a database of simulated historic events (e.g. 1987 and 1988), which can assist (in the long term) to identify optimal operation strategies in real-time situations, but in the short term and within the present study, may serve the purpose of demonstration of the possible benefits of FMM without having to run the hydrodynamic part;
- demonstrate the effects of flood retention in a series of successive compartments on the flood conditions around Dhaka;
- make the DEM for the NCRM, including interfacing to MIKE 11 output and graphic modules available for FAP 10 and test, in cooperation with FAP 10, the possibilities of deriving, off-line, relationships between river water levels and flood plain inundations, also considering effects of direct rainfall, to be used in conjunction with real-time river level forecasting on regional level;

d) Bespoke General FMM:

- establish a close linkage to FAP 10 and the Flood Forecasting and Warning Centre of BWDB to ensure that the proposed development of FMM are fully compatible with the GM-FF (the modified General Model being used for Flood Forecasting) and any regional flood forecasting models being applied, especially the real-time procedures applied in the FF&WC;
- make the DEM for the General Model, including interfacing to MIKE 11 output and graphic modules available for FAP 10 and test, in cooperation with FAP 10, the possibilities of deriving, off-line, relationships between river water levels and flood plain inundations, also considering effects of direct rainfall, to be used in

conjunction with real-time river level forecasting in the major rivers;

e) FMM Demonstration and Training:

- make the various stages of the FMM available to the SWMC as and when they have been developed. The SWMC may use them for training and demonstration purposes and at the same time provide valuable user feedback to the FMM development on overall concept, logics and user friendliness of the FMM
- conduct the third workshop towards the end of the project with a view to demonstrating the full FMM and identify the need of additional developments
- prepare recommendations on training programmes as required for operating the FMM, considering the ongoing, comprehensive training programme under SWSMP-II and institutional responsibility for operation of FMM in accordance with the findings of FAP 26 - Institutional Development Programme

8. ACTIVITY AND REPORTING SCHEDULE

The the FMM study will take place over a two-year period. The project is expected to start in June of 1992. The activity schedule is shown in Fig. 1.

The following reports will be submitted to FPCO (in 50 copies) with copies to the relevant donor agencies of Denmark, France and the Netherlands:

- FMM Inception Report(end of month 3) in September 1992 containing general concepts and logics of FMM; findings of the first workshop and firmed-up methodology and workplan for the entire study;
- First Interim FMM Report (end of month 10) in April 1993 containing the results of Stage 1, general FMM development and an Interim FMM Scientific Documentation;
- Second Interim Report (end of month 17) in November, 1993 describing the further refinement of FMM; progress with the development of bespoke models at compartment, regional and national levels; proposals for final adjustments and recommendations; and an Interim FMM User's Guide;
- Final FMM Report (end of month 24) in June 1994 containing final FMM Scientific Documentation and User's Guide; reporting of development and usage of bespoke models for Tangail compartment, North Central region and testing with General Model for flood forecasting; specifications for further development of FMM to retain its use for off-line and possible on-line applications; recommendations on future institutional responsibility for operating the FMM including needs and programme for required training; and draft TOR for the possible subsequent phase;

9. ORGANISATION ANN TENTATIVE STAFFING

9.1 Organisation

The Implementing Agency of GOB during project implementation will be the Flood Plan Coordination Organisation (FPCO). DANIDA will be the coordinating Donor Agency on behalf of the contributing donors. The Dutch support to the project will be provided through FAP 20, while the French support will come directly under FAP 25.

By its very nature the FMM has strong links to several GOB organisations, particularly the WARPO as host of the SWMC, and the BWDB as host of the Flood Forecasting and Warning Centre (FF&WC). The ultimate institutional host agency of the FMM is therefore likely to be SWMC/WARPO as far as the maintenance, application and further development of the modelling software is concerned; and the FF&WC/BWDB for the ultimate on-line version of the national and regional level FMM. However the final decision on the institutional set-up will be taken later, with due consideration to the recommendations of the FAP 26 Institutional Study.

The project supported by an expatriate **Consultant Team** and a team of local consultants will develop and test the FMM. The expatriate team will be composed of consulting firms from the countries of the contributing donors and with the Danish firm as the lead consultant and responsible towards FPCO and the donors for carrying out the specified duties in accordance with these Terms of Reference. The three donors will enter into separate contracts with the consulting firms.

The **Resident Model Coordinator**, from the Danish consulting firm, will be the Team Leader of FMM. He will be resident in Dhaka up to June 1994 and share his time between the Coordination Advisory Team and FMM as required. The local **Hydraulic Modelling Engineer** will also continue in his coordinating function and also act as deputy Team Leader of the FMM.

The Coordination Advisory Team (CAT) of FAP 25 will advise and assist in the development of the FMM and ensure proper coordination with related activities within and outside the FAP, in close consultation with FPCO.

9.2 Tentative Staffing

The tentative staffing (man-months per calendar year) is shown in Table 9.1 and 9.2 for expatriate and local staff respectively. The detailed job descriptions are found in Annex 1.

Referring to the government agreement between GOB and Denmark on the FAP 25 it is noted that the entire costs of the Resident Model Coordinator should be covered under the project, including 18 m-m under the present project activities (January 1991 to June 1992) and 24 m-m as proposed within these TOR.

Table 9.1: Proposed expatriate man-month input for FMM

	Man-months			
Position	1992	1993	1994	Total
Team Leader *)	3	6	3	12
Computational Hydraulic Engineer	7	11	4	22
FCD Engineer I	2	6	4	12
Software Specialist	5	6	1	12
Short Term Experts	1	2	1	4
Home Office Support	1	1	1	3
GRAND TOTAL	19	32	14	65

*) Also Resident Model Coordinator, for which additional 12 m-m are allocated.

Note: Through FAP 20 another 14 m-m will be provided, i.e. 12 m-m of a FCD Engineer (FCD Engineer II) and 2 m-m short term experts.

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Table 9.2: Proposed Local Man-Month Input for FMM

	Man-months			
Position	1992	1993	1994	Total
Dep. Team Leader *)	3	6	3	12
Modelling Engineer I	7	12	5	24
FCD Engineer	3	12	3	18
Software Specialist	4	12	2	18
Short Term Experts	3	3	3	9
GRAND TOTAL	20	45	16	81

*) Also Hydraulic Modelling Engineer under CAT, for which another 12 m-m are allocated.

Note: Through FAP 20 another 24 m-m will be provided for a Modelling Engineer II

10. RESPONSIBILITIES OF THE GOVERNMENT

10.1 General

The Government/Executing Agency shall bear the cost of any taxes, duties, fees, levies and other impositions imposed under the laws and regulations in effect in Bangladesh on the consultants and expatriate personnel in respect of

- i) any payments made to the consultants or their personnel other than Bangladeshi nationals, in connection with the carrying out of the services;
- ii) any materials, equipment and supplies brought into Bangladesh for purpose of carrying out the services and which after having been brought to the country will be subsequently withdrawn therefrom;
- iii) any equipment imported for the purpose of carrying out the services and paid for out of the funds provided by the Government and which is treated as property of the Government.

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Provided that:

- (a) The Consultant and their expatriate personnel shall follow the usual customs procedure of the Government in importing property into Bangladesh; and
- (b) if the Consultants or any of the expatriate personnel does not withdraw, but disposes of any property in Bangladesh upon which custom duties and taxes have been exempted, the Consultant bear such custom duties and taxes in conformity with the regulations of the Government.

10.2 Other Privileges and Exemptions

Government shall:

- i) provide the Consultant and each of its personnel with work permits and such other documents as shall be necessary to enable them to perform the services including entitlement to the privileges specified in the Government of the People's Republic of Bangladesh notification no SRO/131/D/CUS/74 and SRO/132/DCUS/74 both dated 14th March 1974;
- ii) arrange for the personnel to be provided promptly with all necessary multiple entry and exist visas, residence permit, work permits, exchange permits and travel documents required for their stay in Bangladesh;
- iii) facilitate clearance through customs of any property required for the services and of the personnel effects of the expatriate personnel and the prompt issue to the consultants expatriate personnel of Custom Pass Books.
- iv) arrange for concessions to be given to the Consultants expatriate personnel under SRO.88-L/85/906/CUS and SRO.89-L/85/907/CUS both dated 13.2.85.
- v) issue to officials, agents and representatives of the Government all such instructions as may be necessary or appropriate for the prompt and effective implementation of the services.
- vi) exempt the Consultants and the personnel for the services from any requirement to register or obtain any permit to practice the profession of Engineer or Architect or to establish himself either individually or as a corporate entity according to the laws of Bangladesh.
- vii) arrange for duties and taxes on the imported equipment, vehicles and other materials relating to the project which will be retained in Bangladesh to be paid by the implementing agency in Bangladesh.
- viii) arrange for the Consultant's equipment and materials excluding vehicles and

house hold goods which will be imported and subsequently be re-exported to be cleared free of custom duty and sales tax under temporary importation facility against the project passbook.

- ix) ensure that procedures for approval of expatriate personnel are followed at minimum delay.

10.3 Services, Facilities and Equipment

- (a) The Government shall furnish, free of charge except direct reproduction cost and within a reasonable time, all pertinent data, maps and information available to him and shall give such assistance as shall reasonably be required by the Consultants for the performance of the Services under this Contract.
- (b) Government shall made available free of charge essential services and equipment needed for the performance of the services which are not covered in the cost estimate.
- (c) The Govt. shall, if available, provide accommodation in the Govt. Rest House at usual rate.
- (d) Indemnify save and hold harmless the Consultant and its personnel from and against all claims, demands or suits, that may be made or brought against the Consultant and its personnel arising directly from the performance of the services provided that, such claims, demands or suits are not the result of negligence or wilfully acts of the Consultant and its personnel.

11.0 RESPONSIBILITIES OF THE CONSULTANT

11.1 Responsibility of Consultant

- (a) Consultants shall carryout the services as detailed in "Scope and Term of Reference" in the best interest of the Government for the successful realisation of the program with all reasonable care, skill and diligence with sound hydraulic engineering, administrative and financial practices.
- (b) The Consultant shall during the execution of the services appoint and designate a Team Leader to represent the Consultant in Bangladesh in all matters relating to the services.
- (c) The Consultant shall be responsible for the professional and technical competence of its employee and their personnel behaviour and shall use its best efforts to select and employ for work in Bangladesh only those persons who in its judgement will be the best and most likely to perform satisfactorily the terms of their employment.

- Vto
- (d) The Consultant shall keep accurate and systematic records and accounts in respect of the services in such form and detail as is customary in the profession and shall be sufficient to accurately establish that the costs and expenditures incurred for the services.
 - (e) Except with the prior approval of the Government/Executive Agency the Consultant shall not at any time communicate to any persons or entity not connected with the services any confidential information disclose to them for the purpose of the services or discovered by them in the course of their services, nor shall the Consultant or the Consultant's personnel make public any information relating to the services.
 - (f) The Consultant shall be responsible in respect of life, health, accident, travel and other insurance which may be necessary for the Consultant's personnel for the purpose of the services.

11.2 Information

The Consultant shall furnish the Executing Agency with such information relating to the services and the Project as the Executing Agency may from time to time reasonably request.

11.3 Assignment, Subcontractors:

- (a) Except with the prior written approval of the Government the Consultant shall not assign or transfer the contract or any part thereof nor engage any independent Consultant or sub-contractors to perform any part of the services other than nominated personnel listed in the contract.
- (b) The approval of the Executing Agency to the assignment of any part of the Contract or to the engagement by the Consultant of independent Consultants or sub-contractors to perform any part of the services shall not relieve the Consultant of any of his obligations under this contract.

11.4 Prohibition on Conflicting Activities

No member of the personnel assigned to this Project shall engage, directly or indirectly either in his name or through the Consultant any other conflicting business or professional activities in Bangladesh during the performance of his duties or assignment under this contract.

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11.5 Laws and Regulations of Bangladesh

- (a) This Contract shall be and is deemed to be a Bangladesh Contract and shall accordingly be governed by and construed accordingly to the laws for the time being enforce in Bangladesh.

This formulation not relevant when contract is between donor and consultant, as in the present case

- (b) The Consultant shall respect and abide by all applicable Laws and regulations in Bangladesh and shall use his best efforts to ensure that the expatriate personnel and their dependents while in Bangladesh and local employees of the Consultant shall respect and abide by all laws and regulations of Bangladesh.

11.6 Ownership of Drawings, Data and Reports

All reports and relevant data such as maps, drawing, plans statistics and supporting records or materials compiled or prepared in the course of Services shall be the absolute property of the Government. The Consultant agrees to deliver all these materials to the Executing Agency upon completion or termination of this Agreement. The Consultant may retain copies of such report but shall not use the same for purpose unrelated to this contract without prior written approval of the Government.

11.7 Reports and Communication

All reports, communications, recommendations and general correspondence from the Consultant to the Executing Agency under the Agreement shall be in English Language.

11.8 Notice of Delay

In the event when the Consultant delay in obtaining the required services or facilities set forth in this Contract for the conduct of the services, or the occurrence of any event or condition that might delay or prevent completion of the services in accordance with the time schedule the Consultant shall promptly notify the Government of such delay indicating what steps are being taken or suggested by the Consultant to meet the situation and may request an appropriate extension of time for completion of the services.

11.9 Cooperation

The Consultant shall cooperate fully with the Government in performance of the services for which the Government shall provide the data facilities as set forth in Contract.

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12. COST ESTIMATE

The below cost estimate is divided in two parts. The first part relates to the joint services of the Resident Model Coordinator and Hydraulic Modelling Engineer acting also as Team Leader/Deputy Team Leader of FMM and the second part relates to the FMM development it-self. All price are in US\$.

A. Resident Model Coordinator/Hydraulic Modelling Engineer

-	12 expatriate man-months	225,000
-	12 local man-months	12,000
-	international travels (4 trips)	13,000
-	accommodation, per diems etc. (1 year)	65,000
-	contingencies	30,000

		345,000

B. FMM Development

-	65 expatriate man-months	1,070,000
-	81 local man-months	150,000
-	local support staff	40,000
-	international travels (27 trips)	85,000
-	accommodation,per diems etc.	320,000
-	equipment:	
	computer hardware	50,000
	computer software	65,000
	vehicles, 1 jeep	20,000
	other equipment	10,000
	O&M of 3 vehicles	20,000
	O&M of computer and other	
	office equipment	<u>5,000</u>
		170,000
-	Other project input:	
	Office accommodation, furniture,	
	telephone, electricity,	
	water etc.	40,000
	Office stationary,	
	reporting etc.	15,000
	Additional Data Collection	<u>20,000</u>
		75,000
-	Contingencies	190,000

		2,100,000

GRAND TOTAL	2,445,000
	=====

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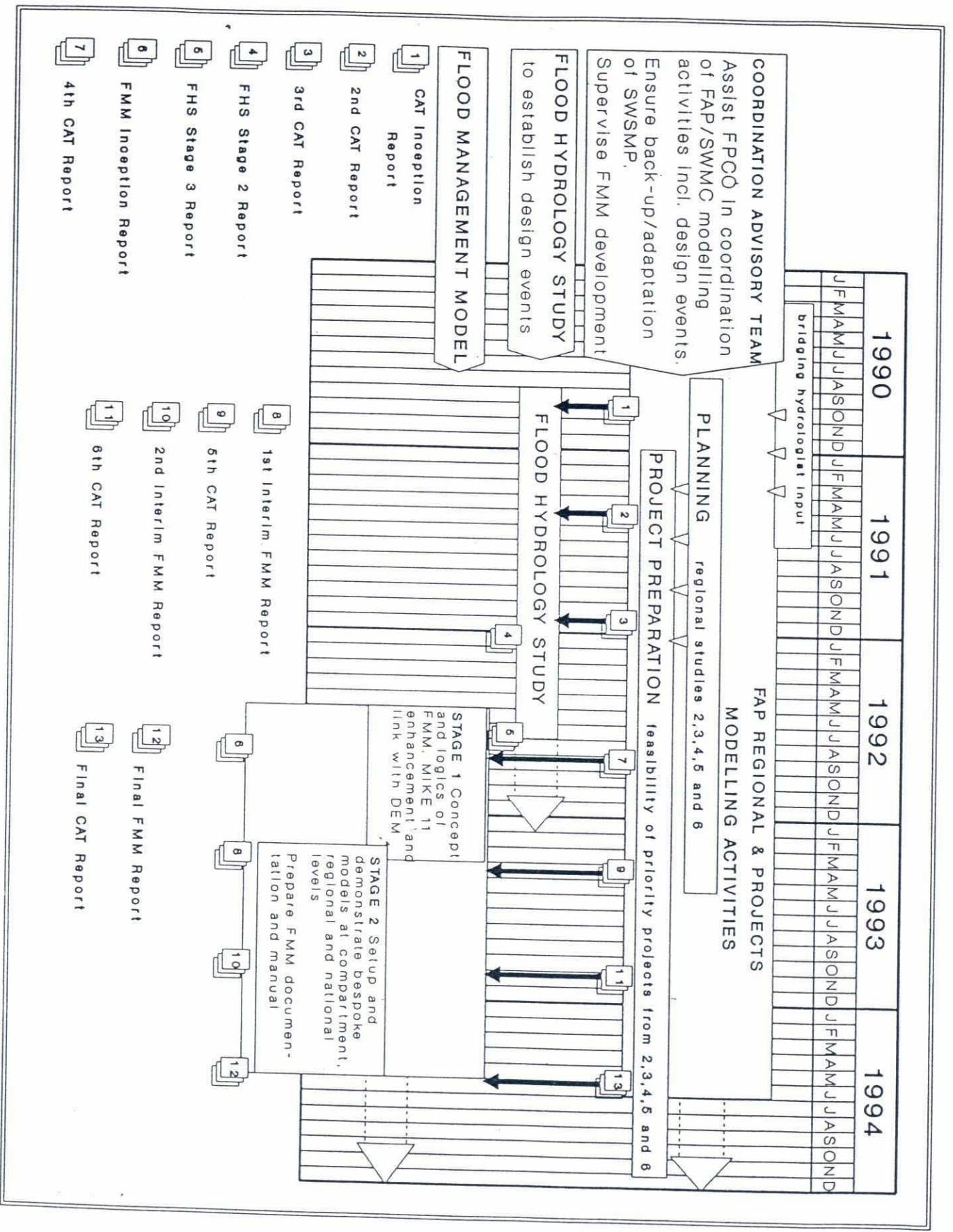


Figure 1: Activity Schedule of FAP 25.

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ANNEX 1 JOB DESCRIPTIONS

1. Expatriate Staff

Computational Hydraulics Engineer

He/she will have a post graduate degree in hydraulic engineering and, preferably, at least ten years of experience in this field. He/she shall have a solid background in computational hydraulics in general and be a specialist in the MIKE 11 model system in particular. Knowledge of GIS will be an additional qualification. He/she will focus on development and modifications and subsequent testing of MIKE 11 core modules as required for the FMM development and applications including linkage with DEM. He/she will ensure the integration between the modelling activities of the SWMC and FAP 25, be involved in the bespoke FMM based on the General Model and liaise with the Flood Forecasting and Early Warning Centre of BWDB. This position will be financed by Denmark.

FCD Engineer I

He/she will have a post graduate degree in irrigation/drainage or hydraulic engineering and, preferably, at least ten years of experience in this field, and also have a solid background in computational hydraulics. He/she will contribute to the general FMM development but focus primarily on the bespoke FMM for the North Central Region. This position will be financed by France.

FCD Engineer II

He/she will have a post graduate degree in irrigation/drainage or hydraulic engineering and, preferably, at least ten years of experience in this field, and also have a solid background in computational hydraulics. He/she will contribute to the general FMM development but focus primarily on the bespoke FMM for the Tangail Compartment. He/she will be available through FAP 20 and be financed by the Netherlands.

Software Specialist

He/she will have a postgraduate degree in programming/software engineering and, preferably, at least eight years of experience in this field. The software specialist will be responsible for acquiring suitable DEM package, for interfacing with MIKE 11 (in cooperation with the Computational Hydraulic Engineer), and for enhancement of graphic facilities for input/output presentation in the FMM. This position will be financed by Denmark.

Short Term Specialists

The short term specialists shall have a post graduate degree in their particular fields and at least twelve years of experience. The areas that may be covered by these specialists include: flood management (including compartmentalisation concept), GIS, economy,

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environment. They will be brought in as required. Two m-m will be financed by the Netherlands through FAP 20 and four m-m by Denmark.

2. Local Staff

Unless otherwise indicated the local staff will be financed by Denmark.

Modelling Engineer I

He/she will have, preferably, a post graduate degree in hydraulic engineering and a minimum of ten years of experience in water resources/mathematical modelling studies. He/she will cooperate with the expatriate Computational Hydraulic Engineer in the general FMM development and application of the bespoke FMM for the General Model.

Modelling Engineer II

He/she will have, preferably, a post graduate degree in hydraulic or irrigation/drainage engineering and a minimum of ten years of experience in water resources/mathematical modelling studies. He/she will work closely together with the Hydraulic Engineer I in developing and applying the bespoke FMM model for Tangail area. He/she will also be involved in establishing and applying model for Serajganj Compartment as required under FAP 20. This position will be financed by the Netherlands through FAP 20.

FCD Engineer

He/she will have, preferably, a post-graduate degree in flood control/drainage engineering and a minimum of ten years of experience in design and operation of flood control, irrigation and drainage systems and knowledge of computational hydraulics. He/she will ensure that practical experience on design, operation and maintenance of such structure/systems are embedded in the development of the FMM on all levels.

Software Specialist

He/she will have, preferably, a postgraduate degree in programming/software engineering and at least five years of experience. He/she will work in close cooperation with the expatriate software specialist covering the similar fields.

Short Term Specialist

The short term specialists shall have a post graduate degree in the particular fields and at least fifteen years of experience. The areas covered by these specialist may include: remote sensing, agronomy, fishing, sociologist and public relation/training. They will be brought in as required. They will be brought in as required.

APPENDIX B - JOB DESCRIPTIONS

POSITION: TEAM LEADER
TYPE: Expatriate

SUMMARY DUTIES/RESPONSIBILITIES:

The Team Leader will have the overall responsibility for the contractual obligations of DHI as agreed with DANIDA; oversee mobilisation, planning, coordination and expenditure activities, carry out budget reviews and ensure that the project objectives are met on time and within the project budget. He will oversee the development and application of the FMM to ensure that the FMM meets the technical specifications in the FMM Terms of Reference. This will involve: supervision and allocation of staff resources; technical discussions; liaison with personnel from related FAP projects; organisation of workshops; and maintaining close links with relevant government authorities. He will work closely with the Deputy Team Leader; liaise on a regular basis with the computational Hydraulics Engineer and the Modelling Engineer I during the development and application stages of the FMM and also with the FCD Engineers during the application of the FMM to the Compartment, Regional and General Models .

POSITION: COMPUTATIONAL HYDRAULICS ENGINEER:

TYPE: Expatriate

SUMMARY DUTIES/RESPONSIBILITIES:

The computational hydraulics engineer will be responsible for the general development, testing, application and documentation of FMM. This will involve: detailing specifications in liaison with the Software Specialists for the interfacing of MIKE 11 with the GIS/DEM and for the graphics and postprocessing enhancements; development, in conjunction with the FCD Engineers, of the modifications and new add-on routines to MIKE 11; liaison with those responsible for the additional field data collection; preparation of the technical reference and user's guide; application of the FMM to the general model and the GM-FF (general model for flood forecasting - FAP 10); demonstration and training of the FMM; reporting. He will liaise with the Flood Forecasting and Early Warning Centre of BWDB. He will work closely with the Modelling Engineer I and maintain close links with the FCD engineers working on the FMM applications to regional and compartment models.

POSITION: SOFTWARE SPECIALIST

TYPE: Expatriate

SUMMARY DUTIES/RESPONSIBILITIES:

The software specialist will be responsible for the development, testing and documentation of the interfaces between MIKE 11 and the GIS/DEM, and the graphics and postprocessing enhancements,

in conjunction with the computational Hydraulics Engineer. He will assist in the mobilisation of the computing facilities, and the acquisition and setting up of the GIS and other software.

POSITION: FLOOD CONTROL AND DRAINAGE ENGINEER-I (FCD-I)

TYPE: Expatriate

SUMMARY DUTIES/RESPONSIBILITIES:

The FCD Engineer I is supported by the French Government and will fulfil the contractual obligations agreed between BCEOM and DHI. He will be responsible for the following activities:

1. Providing specialist advice on the development of FMM.
2. The FMM application to the North Central Region (NCR)
 - Carrying out data capture of the NCR for the FMM and assess data quality, especially the flood plain topography.
 - Assessing result reliability depending on computer technology appropriateness, data quality and simplified mathematical assumptions.
 - Recommending eventual further development for a better FMM calibration and application within NCR.
3. Assisting the FMM application to the General Model.

The FCD Engineer I will work alongside the Local FCD Engineer during Activity 2. They will be responsible for completing the work within the allocated time schedule. The tasks to be carried out are:

- a) Finalize the preparation of plans and MIKE 11 models.
- b) Carry out data capture of the NCR for the FMM.
- c) Apply the FMM to the NCR by performing demonstration runs contents of which have to be agreed by FPCO, CFD and DANIDA. This demonstration runs will be aimed at assessing the effects of: changing the structural arrangement of embankments and compartments; different operation strategies; flood retention in a series of compartments on the flood condition in Dhaka.
- d) Present the results from (c) in the form of flood inundation and hazard maps, and maps showing the impact on flood levels.
- e) Investigate the feasibility of using the FMM for flood forecasting on a regional basis.
- f) Compile a data base of simulated historic events to assist in the identification of optimal operation strategies of FCD structures.
- g) Documentation and reporting on the application of the FMM to the NCR.
- h) Participate in the third and final workshop as a tutor and demonstrator of the NCR FMM application.

The FCD Engineer I will also be required to assist in the application of the FMM to the General Model.

The FCD Engineer I will work closely with the Computational Hydraulic Engineer. Regular meetings will be arranged to discuss how the FMM can be improved based on the experience gained during the NCR FMM Application.

POSITION: FLOOD CONTROL AND DRAINAGE ENGINEER-II (FCD-II)

TYPE: Expatriate

SUMMARY DUTIES/RESPONSIBILITIES:

The Flood Control and Drainage Engineer II is supported by the Netherlands Government through FAP 20 and will be responsible for the FMM application at the compartment level (Tangail Compartment). He will also be required to contribute advice to the development of the structure operation routines for the FMM. He/She will work closely with the local Modelling Engineer-II.

POSITION: DEPUTY TEAM LEADER

TYPE: Local

SUMMARY DUTIES/RESPONSIBILITIES:

The Deputy Team Leader will be the local Hydraulic Modelling Engineer. He/She will have overall responsibility for provision and implementation of GOB input and will together with the Resident Team Leader ensure that project objectives are met.

POSITION: MODELLING ENGINEER-I

TYPE: Local

SUMMARY DUTIES/RESPONSIBILITIES:

The Modelling Engineer I will work closely with the Computational Hydraulic Engineer during the FMM development and the FMM application to the General Model.

POSITION: MODELLING ENGINEER-II

TYPE: Local

SUMMARY DUTIES/RESPONSIBILITIES:

Non

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The Modelling Engineer II will work with the FCD Engineer II on the FMM application to the Tangail Compartment for the FAP 20 Project.

POSITION: FCD ENGINEER

TYPE: Local

SUMMARY DUTIES/RESPONSIBILITIES:

The FCD Engineer will be initially responsible for ensuring that practical experience on design, operation and maintenance aspects of structures and system operations are incorporated into the development and application of the FMM at all levels.

POSITION: SOFTWARE SPECIALIST

TYPE: Local

SUMMARY DUTIES/RESPONSIBILITIES:

The Software Specialist will work alongside the expatriate Software Specialist during the FMM development. During the FMM application he/she will work with the Computational Hydraulics Engineer and carry out modifications to the FMM computer code as required and will assist in the maintenance of the computing facilities. He will be responsible for system administration.

POSITION: SHORT TERM SPECIALISTS

Short term specialists have been identified to contribute to specialised project tasks such as computer system analysis, installation of network and the PC interfaces, communication system, hydrology (Mike11-NAM coupling), embankment breach simulation, structure operation, optimization, etc. The short term specialists are being called in to advise the computational hydraulic engineer, software specialist, flood control and drainage engineers and the team leader as and when required.

APPENDIX C - ADMINISTRATION AND LOGISTICS

C.1 Office Accommodation

The accommodation facilities at House 19, Road 102 used by FAP-25 during the FHS phase were found to be inadequate for the FMM study. A new office of area of about 3800.sq m has been rented at Plot No. CWS(B)33, Road No. 24/30, Gulshan, Dhaka. In addition to adequate office and computer rooms, a large conference room is available. This room has been used by the CAT mission and will be used for holding the coordination meetings under FAP-25. It is also planned to hold the FMM workshops in this hall.

C.2 Staffing

The staff input to date are listed in Table C-1. An individual staff members is identified with his/her company affiliation and the supporting donor.

Table C.1 Project Personnel

<u>S.No.</u>	<u>Position</u>	<u>Name</u>	<u>Affiliation</u>	<u>Donor</u>	<u>Start Date</u>
1.	Team Leader	Guna N Paudyal	DHI	DANIDA	19.10.92
2.	Computational Hydraulic Engineer	Bill Syme	DHI	"	03.11.92
3.	Software Specialist	Kirk Kuykendall	DHI	"	19.10.92
4.	FCD Engineer-II	Johan Crebas	Euroconsult/FAP20	Netherlands	31.10.92
5.	FCD Engineer-I	David Milton	BCEOM	CFD	1.11.92
6.	Home Office Support	Karsten Havno	DHI	DANIDA	19.10.92
7.	Short term Experts	Gregors Jorgensen Henrik Sorensen Jesper Kjelds Lars Yde Terrence van Kalken Morten Kmudsen	DHI		
9.	Short term Expert	To be allocated	DHI	DANIDA Netherlands	
<u>Local Staff</u>					
1.	Hydraulic Modelling Engineer	Emaduddin Ahmad -		DANIDA	19.10.92
2.	Modelling Engineer-I	Fazle Rabbi -		"	19.10.92

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3.	Modelling Engineer-II	Mustafa Kamal	FAP20	Netherlands	1.11.92
4.	FCD Engineer	Jahangir Islam		DANIDA	1.12.92
5.	Software Specialist	Manzur Alam Shahed		DANIDA	30.1.93
6.	Assistant Engineer(GIS)	Nawajish Sayeed Noman		DANIDA	1.12.92
7.	Short term Experts	To be allocated			

Local Support Staff.

1.	Office Manager/Accountant	Salahuddin Ahmed
2.	Secretary	Md. Ziaul Hoque
3.	Receptionist/Secretary	Hanna Soren
4.	Driver	Md. Khalilur Rahman
5.	Driver	Md. Faruke
6.	Driver	Tota Miah
7.	Caretaker	Md. Abul Kashem
8.	Guard	Md. Abdul Malek
9.	Guard	Md. Nannu Miah
10.	Guard	Md. Asadullah
11.	Guard	Md. Akhter Hossain
12.	Office Cleaner	Achia Begum

C.3 Transport

Two vehicles (1 Toyota Liteace Van, 1 Toyota Sprinter Sedan) were taken over from FAP-25 Phase I, Another Toyota Corolla (reconditioned) has been purchased. It is proposed to hire a 4 wheel drive jeep for field trips when required.

C.4 Computers and Related Hardware

Based on an extensive market survey and in view of the advance computing requirements it was decided to base the FMM development in UNIX Work Stations. Two HP Work Stations with the following specifications are installed. In addition to the WS all the PCs are connected to the ethernet network and used as terminals via a PC terminal emulation software. The network configuration is presented in Fig C.1.

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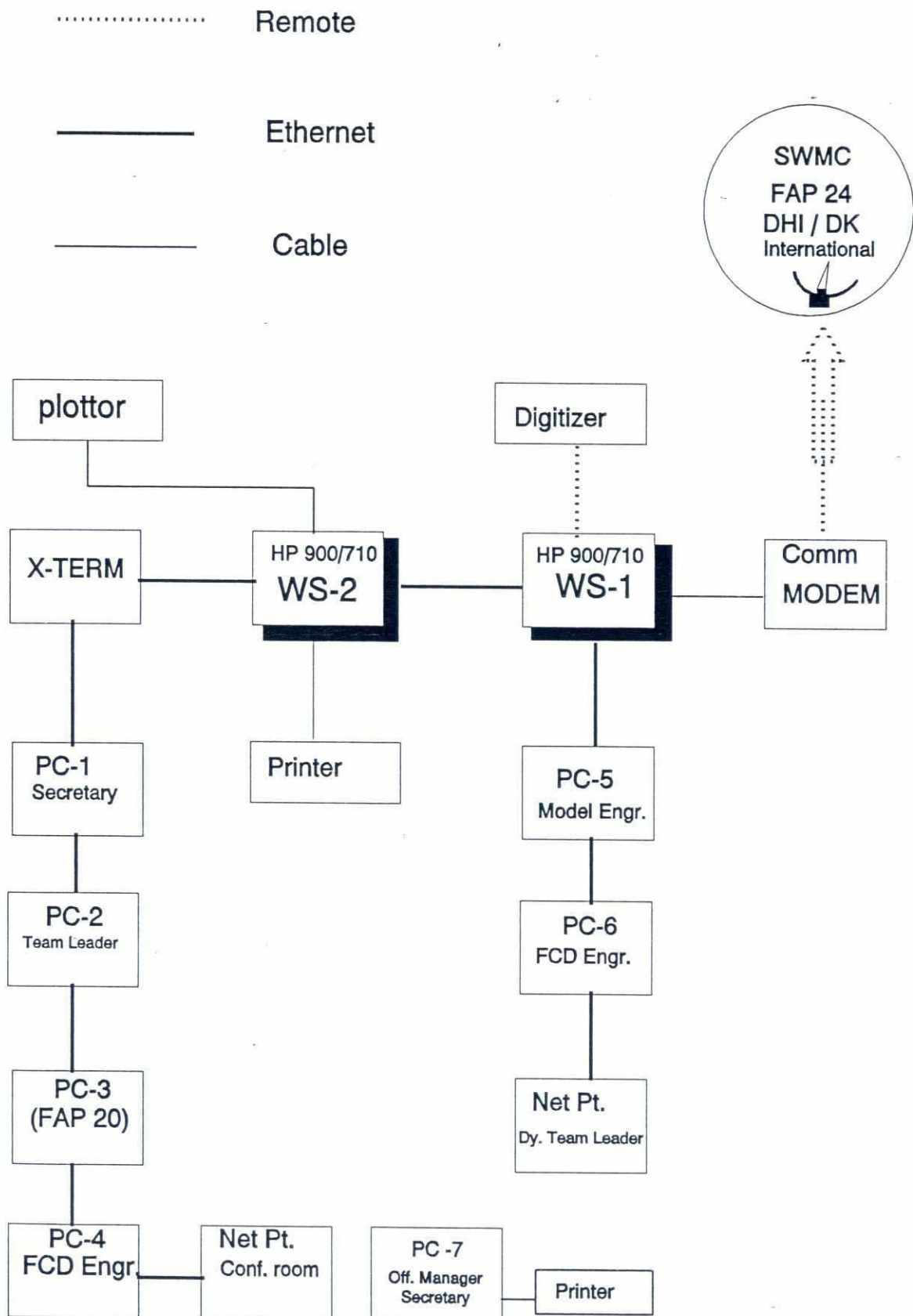


Figure C.1 Computer Network Configuration

*Specification of Computers***WS-1**

HEWLETT PACKARD 9000/710 (RISC)
660 MB disk
32 MB RAM
CD ROM drive

WS-2

HEWLETT PACKARD 9000/710 (RISC)
660 MB disk
24 MB RAM
DAT tape drive

X-Term

HP R x 700

PC-1 (Secretary)

EPSON Ax3s
80386 15MHz
80387 Math co-processor
VGA
82 MB HD
1.2, 1.44 MB floppy

PC-3 (FAP 20)

Datamini PT 386
80386 25MHz
80387 Co-processor
VGA
4 MB RAM
207 MBHD
1.44 B floppy
1.2 MB floppy

PC-4

WDS

C-4

Datamini
80486 20MHz
VGA
4 MG RAM
83 MB Hard disk
1.44 MB floppy
1.2 MB floppy

PC-5

EPSON - PC Ax3/25
80386 25 MHz
80387 Co - Processor
VGA
4 MB RAM
330M 122 M HD
Floppy 1.2 M 1.44 M

PC-6 (Administration)

EPSON PC Ax2
80286 12 MHz
Monochrome
640 K RAM
1.44 MB floppy
31 MB HD

Digitizer

CalComp
Model 33480
36"x48"

Plotter

CalComp
Model 2024

Networks' Cards

Elite 16 Series
16 - bit Ethernet Network Cards
Supporting Thin Ethernet cable

Communication modem

Telebit T2500

UPS

1 KVA Emersion Accupower Gold 2 sets
 0.800 KVA Emersion 1 set
 0.500 KVA 2 sets

C.5 Software

The following software have been procured and installed.

1. ARC/Info
3 node licence/including GRID
2. MIKE 11 3.01 UNIX
 3.01 DOS
3. C++ Compiler
4. F77
5. PCNSF, PC X Sight

In addition to the above, several utility software are in use continued from the FHS phase of FAP 25.

C.6 Maps and Photographs

The following maps have been procured for the NCR

1:50,000 maps of the NCR

Sheet Nos.

- | | |
|----|---|
| 78 | G-9 to 16,
K-4,
F-12,
F-16.
H-9 to 16,
L-1 to 8,
L-10 to 12 |
| 79 | E-10,
E-11,
E-14 |

I-1 to 3
I-5 to 8
I-10 to 12

Aerial Photos

AERIAL Photos scale 1/50,000 year : 1990 NCRS							
From - to				From - to		From - to	
Line	No.	No.	No.	No.	No.	No.	Total
L-004	195	201					7
L-005	240	257	270				29
L-006	424	460					37
L-007	55	87					33
L-008	475	507					33
L-009	598	609	616	630	663	674	39
L-010	576	589	596	596	638	653	31
L-011	530	564					35
L-015	590	595					6
L-016	655	662					8
							258

APPENDIX D1 - DATA AVAILABILITY FOR THE NC REGION

Table D1.1 Summary of Data Collection

STATION TYPE	NUMBER IN YEAR							
	1986	1987	1988	1989	1990	1991	1992	1993
RAINFALL	33	33	33	33	33	35	35	
CLIMATIC	6	6	-	6	6	6	3	
GROUND WATER	18	18	18	18	18	18	18	
DISCHARGE	-	14	13	14	26	24	25	
SUSPENDED SEDIMENT	-	-	-	-	-	4	4	
WATER LEVEL(NT)	-	25	25	24	38	31	32	
WATER LEVEL (T)	-	18	20	20	18	18	17	
CROSS SECTIONS	10	26	59	50	181	179	6	
NO OF BED SAMPLES	-	-	-	-	-	72	12	

Source SWMC

Table D1.2 Rainfall Stations

NAME	NO	CATCHMENT NO	FIRST RECORD	LAST RECORD
Atia	R-2	NC-9	Apr 86	Mar 92
Bhaluka	R-5	NC-7	Apr 86	Mar 92
Dhaka	R-9	NC-17	Apr 86	Mar 92
Daulatpur	R-10	NC-13	Apr 86	Mar 92
Gopalpur	R-13	NC-6	Apr 86	Mar 92
Joydevpur	R-17	NC-11	Apr 86	Mar 92
Kalihati	R-18	NC-6	Apr 86	Mar 92
Manikganj	R-20	NC-16	Apr 86	Mar 92
Mirzapur	R-21	NC-9	Apr 86	Mar 92
Phulbaria	R-27	NC-4	Apr 86	Mar 92
Savar	R-31	NC-15	Apr 86	Mar 92
Sharishabari	R-32	NC	Apr 86	Mar 92
Sreepur	R-37	NC-11	Apr 86	Mar 92
Bajitpur	R-61	NE	Apr 86	Mar 92
Dewanganj	R-62	NC	Apr 86	Mar 92
Gaffargaon	R-64	NC-8	Apr 86	Mar 92
Gouripur	R-65	NE	Apr 86	Mar 92
Jamalpur	R-67	NC-4A	Apr 86	Mar 92
Kishoreganj	R-71	NC-8	Apr 86	Mar 92
Muktagacha	R-72	NC-5	Apr 86	Mar 92
Mymensingh	R-73	NC-1	Apr 86	Mar 92
Nalitabari	R-74	NE	Apr 86	Mar 92
Nandail	R-75	NE	Apr 86	Mar 92
Narsingdi	R-76	NC-18	Apr 86	Mar 92
Phulpur	R-77	NE	Apr 86	Mar 92
Sherpur Town	R-78	NC-1	Apr 86	Mar 92
Shibpur	R-79	NC-18	Apr 86	Mar 92
Bhairab Bazar	R-101	NE	Apr 86	Mar 92
Munshiganj	R-365	NC	Apr 86	Mar 92
Bhagyakul	R-402	NC	Apr 86	Mar 92
Nawabganj	R-412	NC-16	Apr 86	Mar 92
Shimrail	R-519	NC-17	Apr 86	Mar 92
Rasulpur	NCR-1	NC-6	May 91	Mar 92
Kutubpur	NCR-2	NC-7	May 91	Mar 92
Maona	NCR-3	NC-10	May 91	Mar 92

Source SWMC

- Note: (1) Measurements are taken daily at 9.00am.
- (2) NE is a station within the north east region used to construct the Thiessen polygon.

Table D1.3 Evaporation Stations

NAME	NUMBER	CATCHMENT NUMBER	FIRST RECORD	LAST RECORD
Dewanganj	E-45	NC	1986	1992
Shimrail	E-46	NC-17	1986	1992
Jamalpur	E-16	NC-4A	1986	1992
Mymensingh	E-24	NC-1	1986	1992
Bhagyakul	E-43	NC	1986	1992
Mirpur	E-13	NC-15	1986	1992
Maona	NCE-3	NC-10	1991	1992

Source SWMC

- Note: (1) Measurements are taken daily at 9.00am.
- (2) 1988 records are missing for all stations.

Table D1.4 Selected ground water observation wells
(representative well in each subcatchment)

CATCHMENT NO	PIEZOMETRIC WELL	HAND DUG WELLS	TOTAL NO	FIRST RECORD	LAST RECORD
NC-1	-	JAM12	1	Apr 86	Dec 91
NC-2	JAM08	-	1	Apr 86	Dec 91
NC-3	TAN04	-	1	Apr 86	Dec 91
NC-4A	MYM30	-	1	Apr 86	Dec 91
NC-4	MYM30	-	1	Apr 86	Dec 91
NC-5	-	MYM52	1	Apr 86	Dec 91
NC-6	-	TAN15	1	Apr 86	Dec 91
NC-7	MYM60	-	1	Apr 86	Dec 91
NC-8	-	MYM76	1	Apr 86	Dec 91
NC-9	TAN02	-	1	Apr 86	Dec 91
NC-10	-	DHA100	1	Apr 86	Dec 91
NC-11	DHA09	-	1	Apr 86	Dec 91
NC-12	-	DHA11	1	Apr 86	Dec 91
NC-13	TAN23	-	1	Apr 86	Dec 91
NC-14	-	DHA92	1	Apr 86	Dec 91
NC-15	DHA70	-	1	Apr 86	Dec 91
NC-16	-	DHA01	1	Apr 86	Dec 91
NC-17	DHA13	-	1	Apr 86	Dec 91
NC-18	-	DHA12	1	Apr 86	Dec 91

Source SWMC

Note: Measurements are taken daily at 9.00am.

Table D1.5 River Cross Sections

River	Chainage (km.)		Distance (km.)	No. of Sections	Source	Survey Years
	From	To				
Arial Khan	0.0	49.0	49.0	8	SWMC	1991
Balu	0.0	30.0	30.0	8	BWDB	1989
Banar	25.0	120.0	95.0	13	BWDB	1979
	91.0	120.0	29.0	6	DUL	1990
	37.0	91.0	54.0	10	SWMC	1991
	84.0	84.0	at confl.	1	SWMC	1991
Bangshi	0.0	153.0	153.0	26	BWDB	1987
Bangshi_east	0.0	15.0	15.0	2	SWMC	1992
Bansi-South	31.0	70.6	39.6	8	DUL	1990
Barinda	0.0	30.7	30.7	8	DUL	1990
Buriganga	0.0	21.5	21.5	8	BWDB	1989
Chatal	0.0	58.0	58.0	13	DUL	1990
Chatal_south	0.0	9.3	9.3	10	JPPS	1991
	9.3	19.6	10.3	3	DUL	1990
Dadbhanga	0.0	43.2	43.2	43	JPPS	1991
Deonai	0.0	18.0	18.0	2	SWMC	1991
Dhaleswari	8.5	148.0	139.5	23	BWDB	1988
	8.5	148.0	139.5	23	BWDB	1991
Old Dhaleswari	0.0	46.1	46.1	12	JBA	1991
Spill-1	0.0	6.5	6.5	4	JBA	1991
Spill-2	0.0	7.2	7.2	3	JBA	1991
Spill-3	0.0	8.5	8.5	3	JBA	1991
Makar khal	0.0	8.6	8.6	3	JBA	1991
Dhantara	0.0	14.2	14.2	4	DUL	1990
Elangjani	0.0	28.0	28.0	7	DUL	1990
Futikjani	0.0	51.0	51.0	16	DUL	1990
Haridoo	0.0	36.5	36.5	3	SWMC	1991
Jhenai	0.0	95.0	95.0	22	DUL	1990
Jhenai East	0.0	36.8	36.8	8	DUL	1990
Jhenai West	0.0	12.2	12.2	5	DUL	1990
Kaliganga	0.0	62.0	62.0	10	BWDB	1986
Kaoraid	0.0	15.0	15.0	4	DUL	1990
Karnatali	0.0	11.4	11.4	4	DUL	1990
Khiro	0.0	68.0	68.0	16	DUL	1990
	0.0	17.5	17.5	3	SWMC	1991
Lakhya	0.0	112.5	112.5	19	BWDB	1989
Louhaganj	0.0	59.8	59.8	15	DUL	1990
Nanglai_N	0.0	23.0	23.0	4	DUL	1990
Nanglai-S	0.0	16.0	16.0	4	DUL	1990
Old Brahmaputra	0.0	12.0	12.0	3	SWMC	1991
	12.0	241.0	229.0	36	BWDB	1988
	12.0	241.0	229.0	36	BWDB	1991
Pungli	0.0	55.5	55.5	12	DUL	1990
Patharkata	0.0	8.0	8.0	7	JPPS	1991
Sutia	0.0	62.0	62.0	14	DUL	1990
Tongi Khal	0.0	15.0	15.0	4	DUL	1990
	0.0	15.0	15.0	3	BWDB	1989
Turag	0.0	14.0	14.0	4	DUL	1990
	14.0	37.0	23.0	4	SWMC	1992
	37.0	68.0	31.0	9	BWDB	1989
Ichamati	0.0	44.0	44.0	5	SWMC	1991

Source SWMC

BWDB : Bangladesh Water Development Board

JBA : Jamuna Bridge Authority

DUL : Desh Upodesh (Pvt) Limited

Table D1.6 BWDB Hydrometric Stations in NCR

BWDB NO.	STATION NAME	RIVER	TD/ NT	PERIOD OF RECORD	MISSING YEARS
7	PUBAIL	BALU	TD	1945/1989	64/67, 78/79, 81,82
7.5	DEMRA	BALU	TD	1962/1989	64/67, 85,88
8	BASURI	BANAR	NT	1976/1989	80
9	KAORAI	BANAR	TD	1964/1989	67,71
9.5	TRIMOHINI	BANAR	NT	1968/1989	82/84
12	MADHUPUR	BANGSHI	NT	1957/1989	
13	KAULJANI	BANGSHI	NT	1959/1989	83
14	MIRZAPUR	BANGSHI	NT	1945/1989	64/76, 79, 85
14.5	NAYERHAT	BANGSHI	TD	1968/1989	71, 85/86, 88
42	DHAKA M. BARAK	BURIGANGA	TD	1909/1989	62/67, 76, 88
43	HARIHARPUR	BURIGANGA	TD	1945/1989	48/52, 62/67, 78, 82
46.9L	BAHADURABAD TR.	JAMUNA	NT	1949/1989	
48	JAGANNATHGANJ	JAMUNA	NT	1962/1989	63, 81/82
49	SERAJGANJ	JAMUNA	NT	1945/1989	59/61, 63, 71
50	PORABARI	MAKAR	NT	1940/1989	59/61, 63, 80
50.6	ARICHA	PADMA	NT	1964/1989	
68	TILLI	DHALESWARI	NT	1949/1989	58, 62/63
68.5	JAGIR	DHALESWARI	NT	1964/1989	71
69	SAVAR	DHALESWARI	TD	1945/1989	62/67, 79/82, 85
70	KALATIA	DHALESWARI	TD	1968/1989	76, 79, 82
71	KALAGACHIA	DHALESWARI	TD	1945/1987	50/51, 62/69, 78/82
71A	RAKABI BAZAR	DHALESWARI	TD	1968/1989	76, 78/79, 81/82
91.9L	BARURIA TR.	JAMUNA	NT	1964/1989	

BWDB NO.	STATION NAME	RIVER	TD/ NT	PERIOD OF RECORD	MISSING YEARS
93.5L	MAWA	PADMA	TD	1968/1989	87/88
134	JOKERCHAR	PUNGLI	NT	1958/1989	
134A	BAUSHI R.B.	JHENAI	NT	1965/1989	71
134B	OFFTAKE JHENAI	JHENAI	NT	1966/1989	71, 80
137A	TARAGHAT	KALIGANGA	NT	1964/1989	71
177	LAKPUR	LAKHYA	TD	1968/1989	78/81, 85, 88
179	DEMRA	LAKHYA	TD	1952/1989	59/63, 70, 83
186	JUGINI	OLD DHALESWARI	NT	1945/1989	47, 59/63, 79/80, 82
225	JAMALPUR	OLD BRAHMAPUTRA	NT	1945/1989	82/85
227	OFFTAKE OLD BRAHMAPUTRA	OLD BRAHMAPUTRA	NT	1959/1989	71
228	MYMENSINGH	OLD BRAHMAPUTRA	NT	1944/1989	48/56, 59/60, 71
229	TOKE	OLD BRAHMAPUTRA	TD	1948/1989	64/69, 81/82
230.1	B. BAZAR R.B.	OLD BRAHMAPUTRA	TD	1964/1989	
273	BHAIRAB BAZAR	OLD BRAHMAPUTRA	TD	1959/1989	62/67
299	TONGI	TONGI KHAL	TD	1960/1989	64/67, 81
301	KALIAKOIR	BANGSHI	NT	1949/1989	81, 83
302	MIRPUR	TURAG	TD	1952/1989	67, 71

Source FAP 25

Table D1.7 Supplementary Hydrometric Stations in NCR

No.	NAME	RIVER	PERIOD OF RECORD	SOURCE	REMARKS
S1	PATERGHATA	BANGSHI	JUL.-NOV.'92	FAP-3	
S2	BASAI	NANGLAI_S	JUL.-NOV.'92	FAP-3	
S3	DHALPARA	BANGSHI	JUL.-NOV.'92	FAP-3	
S4	ICHAPUR	NANGLAI_N	JUL.-NOV.'92	FAP-3	
S5	BHUAPUR REG.	FUTIKJANI	JUL.-NOV.'92	FAP-3	
S6	SAKHARIA	BOALBARI KHAL	JUL.-NOV.'92	FAP-3	
SG1	MADARGANJ	CHATAL	MAY-OCT.'90	FAP-3	
SG2	KAYRA	JHENAI	MAY-OCT.'90 JUL.-NOV.'92	FAP-3	
SG3	BENGHULA	JHENAI	MAY-OCT.'90	FAP-3	
SG4	GOPALPUR	JHENAI	MAY-OCT.'90	FAP-3	
SG5	BELUA BAZAR	JHENAI	MAY-OCT.'90 JUL.-NOV.'92	FAP-3	
SG6	BHUAPUR	FUTIKJANI	MAY-OCT.'90	FAP-3	
SG7	CHARAN	FUTIKJANI	MAY-OCT.'90 JUL.-NOV.'92	FAP-3	
SG8	SUROOJ	PUNGLI	MAY-OCT.'90 JUL.-NOV.'92	FAP-3	
SG9	KAGMARI	LOUHAJANG	MAY-OCT.'90	FAP-3	
SG10	HINGANAGAR	ELANGJANI	MAY-OCT.'90 JUN.-AUG.'91	FAP-3 SWMC	
SG11	BENUPUR	DHANTARA KHAL	MAY-OCT.'90	FAP-3	
SG12	PHULBARIA	KHIRO_S	MAY-NOV.'90	FAP-3	
SG13	NARAYANPUR	BANAR	MAY-OCT.'90	FAP-3	
SG14	TRISAL	SUTIA	MAY-NOV.'90	FAP-3	
SG15	TONGI	TONGI KHAL	MAY-OCT.'90	FAP-3	
NCQ1	MADARGANJ	CHATAL	APR.'91-MAR.'93	SWMC	ON GOING

No.	NAME	RIVER	PERIOD OF RECORD	SOURCE	REMARKS
NCQ2	NOLSAFA	FUTIKJANI	APR. '91-MAR. '93	SWMC	ON GOING
NCQ3	MIRZAPUR	LOUHAJANG	APR. '91-MAR. '93	SWMC	ON GOING
NCQ4	JHALARCHAR	OLD BRAHMAPUTRA	APR. '92-MAR. '93	SWMC	ON GOING
NCQ5	KOMOLPUR	ICHAMATI	APR. '91-MAR. '93	SWMC	ON GOING
NCQ6	ELASHIN	DHALESWARI	APR. '91-MAR. '93	SWMC	ON GOING
NCQ8	KHIRO TRUSS BRIDGE	KHIRO	APR. '92-MAR. '93	SWMC	ON GOING
NCQ9	SHIBGANJ	BANAR	APR. '92-MAR. '93	SWMC	ON GOING
NCQ11	PHULBARI	GOALLAR KHAL	APR. '92-MAR. '93	SWMC	ON GOING
NCW1	BHALUKJAN	KHIRO	APR. '92-MAR. '93	SWMC	ON GOING
NCW4	KRISHNAPARA	GAZIKHALI	APR. '92-MAR. '93	SWMC	ON GOING
	ISLAMPUR	PATHERKATA KHAL	MAY-SEP. '92	FAP-3.1	
	POILAR BRIDGE	MADARDHAW KHAL	MAY-SEP. '92	FAP-3.1	
	CHARADIRPARA	DADBHANGA KHAL	MAY-SEP. '92	FAP-3.1	
	BHELAMATI	CHATAL SPILL CHANNEL	MAY-SEP. '92	FAP-3.1	
	HARIPUR	CHATAL/JHENAI U/S CONFL.	MAY-SEP. '92	FAP-3.1	
	SARISHABARI	CHATAL/JHENAI D/S CONFL.	MAY-SEP. '92	FAP-3.1	
	GAMARIA	DELYER KHAL	MAY-SEP. '92	FAP-3.1	
G-1		LOUHAJANG	MAY-NOV. '91	FAP-20	
G-2		LOUHAJANG	MAY-NOV. '91	FAP-20	
G-3		LOUHAJANG	MAY-NOV. '91	FAP-20	
G-4		LOUHAJANG	MAY-NOV. '91	FAP-20	
G-8		ELANGJANI	MAY-NOV. '91	FAP-20	
G-10		PUNGLI	MAY-NOV. '91	FAP-20	
G-11		PUNGLI	MAY-NOV. '91	FAP-20	

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No.	NAME	RIVER	PERIOD OF RECORD	SOURCE	REMARKS
S1	PATERGHATA	BANGSHI	JUL.-NOV.'92	FAP-3	
S2	BASAI	NANGLAI_S	JUL.-NOV.'92	FAP-3	
S3	DHALPARA	BANGSHI	JUL.-NOV.'92	FAP-3	
S4	ICHAPUR	NANGLAI_N	JUL.-NOV.'92	FAP-3	
S5	BHUAPUR REG.	FUTIKJANI	JUL.-NOV.'92	FAP-3	
S6	SAKHARIA	BOALBARI KHAL	JUL.-NOV.'92	FAP-3	
SG1	MADARGANJ	CHATAL	MAY-OCT.'90	FAP-3	
SG2	KAYRA	JHENAI	MAY-OCT.'90 JUL.-NOV.'92	FAP-3	
SG3	BENGHULA	JHENAI	MAY-OCT.'90	FAP-3	
SG4	GOPALPUR	JHENAI	MAY-OCT.'90	FAP-3	
SG5	BELUA BAZAR	JHENAI	MAY-OCT.'90 JUL.-NOV.'92	FAP-3	
SG6	BHUAPUR	FUTIKJANI	MAY-OCT.'90	FAP-3	
SG7	CHARAN	FUTIKJANI	MAY-OCT.'90 JUL.-NOV.'92	FAP-3	
SG8	SUROOJ	PUNGLI	MAY-OCT.'90 JUL.-NOV.'92	FAP-3	
SG9	KAGMARI	LOUHAJANG	MAY-OCT.'90	FAP-3	
SG10	HINGANAGAR	ELANGJANI	MAY-OCT.'90 JUN.-AUG.'91	FAP-3 SWMC	
SG11	BENUPUR	DHANTARA KHAL	MAY-OCT.'90	FAP-3	
SG12	PHULBARIA	KHIRO_S	MAY-NOV.'90	FAP-3	
SG13	NARAYANPUR	BANAR	MAY-OCT.'90	FAP-3	
SG14	TRISAL	SUTIA	MAY-NOV.'90	FAP-3	
SG15	TONGI	TONGI KHAL	MAY-OCT.'90	FAP-3	
NCQ1	MADARGANJ	CHATAL	APR.'91-MAR.'93	SWMC	ON GOING
NCQ2	NOLSAFA	FUTIKJANI	APR.'91-MAR.'93	SWMC	ON GOING
NCQ3	MIRZAPUR	LOUHAJANG	APR.'91-MAR.'93	SWMC	ON GOING

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No.	NAME	RIVER	PERIOD OF RECORD	SOURCE	REMARKS
NCQ4	JHALARCHAR	OLD BRAHMAPUTRA	APR.'92-MAR.'93	SWMC	ON GOING
NCQ5	KOMOLPUR	ICHAMATI	APR.'91-MAR.'93	SWMC	ON GOING
NCQ6	ELASHIN	DHALESWARI	APR.'91-MAR.'93	SWMC	ON GOING
NCQ8	KHIRO TRUSS BRIDGE	KHIRO	APR.'92-MAR.'93	SWMC	ON GOING
NCQ9	SHIBGANJ	BANAR	APR.'92-MAR.'93	SWMC	ON GOING
NCQ11	PHULBARI	GOALLAR KHAL	APR.'92-MAR.'93	SWMC	ON GOING
NCW1	BHALUKJAN	KHIRO	APR.'92-MAR.'93	SWMC	ON GOING
NCW4	KRISHNAPARA	GAZIKHALI	APR.'92-MAR.'93	SWMC	ON GOING
	ISLAMPUR	PATHERKATA KHAL	MAY-SEP.'92	FAP-3.1	
	POILAR BRIDGE	MADARDHAW KHAL	MAY-SEP.'92	FAP-3.1	
	CHARADIRPARA	DADBHANGA KHAL	MAY-SEP.'92	FAP-3.1	
	BHELAMATI	CHATAL SPILL CHANNEL	MAY-SEP.'92	FAP-3.1	
	HARIPUR	CHATAL/JHENAI U/S CONFL.	MAY-SEP.'92	FAP-3.1	
	SARISHABARI	CHATAL/JHENAI D/S CONFL.	MAY-SEP.'92	FAP-3.1	
	GAMARIA	DELYER KHAL	MAY-SEP.'92	FAP-3.1	
G-1		LOUHAJANG	MAY-NOV.'91	FAP-20	
G-2		LOUHAJANG	MAY-NOV.'91	FAP-20	
G-3		LOUHAJANG	MAY-NOV.'91	FAP-20	
G-4		LOUHAJANG	MAY-NOV.'91	FAP-20	
G-8		ELANGJANI	MAY-NOV.'91	FAP-20	
G-10		PUNGLI	MAY-NOV.'91	FAP-20	
G-11		PUNGLI	MAY-NOV.'91	FAP-20	

APPENDIX D2 - SURVEY PROGRAM FOR THE NC REGION

Survey Programme

(The following programme is directly abstracted from a working document of SWMC)

Guide Line for Embankment Survey

1. Any BM/TBM lying on the route of the embankment survey should be connected and their values should be checked to verify the accuracy of the survey.
2. Each survey team will carry out embankment survey along both banks of the river. Where embankment is not existing, survey will be carried along the alignment of any natural levee on both banks of the river.
3. Ground levels on the embankment or natural levee along both banks of the river are to be taken at every 200 m interval. Three representative spot levels at interval 30, 60 and 60 meters on the flood plains perpendicular to the line of survey are also to be taken at every 1 km interval along both sides of the river.
4. Where a small khal or channel connects the river, levels should be taken at every 30 m or 10 m depending upon the size of the channel. If hydraulic structures e.g. culverts, regulators exist along the embankment, its size and sill level should be taken.
5. In each couple days as appeared in the schedule, on both banks of the river to be surveyed up to 'T' marked points where established TBMs on both banks are to be connected.
6. GPS location of the embankment or natural levee along both banks of the river should be taken at 1 km interval. The location of the structures and the intersecting khals or channels along the embankment or natural levee should also be taken by GPS.

Embankment Survey Programme-I

- Location:** Embankment survey along both banks of the rivers Futikjani(partly), Bangshi and Dhaleswari(partly).
- Duration:** March 14-23 and March 29 - June 6, 1993. Total 80 (eighty) days.
- Work volume:** Both banks each 133 km = Total 266 km.
No. of WL gauge stations to check = 5.
- Bench Mark:** FINNMAP BM# 5803 at Chamuria near Kalihati.
- Participants:** One surveyor, one Assistant Surveyor and four locally employed workers.

The Schedule Programme

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<u>Date</u>		<u>Camp</u>	<u>Work Start-Finish</u>	<u>Remarks</u>
March	14	Tangail		Reconnaissance
	15-16	-do-	BM# 5803-T04	
	17-18	-do-	T04-T08	
	19-20	-do-	T08-T12	
	21-22	-do-	T12-T16	
	23	--	--	Return to office
	24-28	--	--	Eid vacation
	29	--	--	Leave office
	30-31	-do-	T16-T19	Check <u>Kawaljani 13</u>
April	01	--	--	Shift camp to Basail
	02-03	Basail	T19-T22	
	04-05	-do-	T22-T25	
	06-07	-do-	T25-T29	
	08-09	-do-	T29-T33	
	10-11	-do-	T33-T37	
	12-13	-do-	T37-T41	
	14-15	-do-	T41-T45	
	16-17	-do-	T45-T49	
	18-19	-do-	T49-T53	
	20-21	-do-	T53-T57	
	22	--	--	Camp shifting
	23-24	Mirzapur	T57-T61	
	25-26	-do-	T61-T65	
	27-28	-do-	T65-T68	Check <u>Mirzapur 14</u>
	29-30	-do-	T68-T72	
May	01-02	-do-	T72-T76	
	03-04	-do-	T76-T80	
	05	--	--	Camp shifting
	06-07	Kaliakoir	T80-T84	Check <u>Kaliakoir 301</u>
	08-09	-do-	T84-T88	
	10-11	-do-	T88-T92	
	12-13	-do-	T92-T95	
	14	--	--	Camp shifting
	15-16	Dhamrai	T95-T98	
	17-18	-do-	T98-T101	
	19-20	-do-	T101-T104	
	21-22	-do-	T104-T108	Check <u>Nayerhat 14.5</u>
	22-23	-do-	T108-T112	
	25	--	--	Camp shifting
	26-27	Savar	T112-T116	Check <u>Savar 69</u>
	28-29	-do-	T116-T120	
	30-31	-do-	T120-T124	
June	01-02	-do-	T124-T127	

03-04 -do- T127-T130
05-06 -do- T130-T133

Embankment Survey Programme-II

Location: Embankment survey along both banks of the rivers Turag, Tongi Khal(partly), and Buriganga.

Duration: April 4 - May 28, 1993. Total 55 (fifty five) working days.

Work volume: Both banks each 98 km = Total 196 km.
No. of WL gauge stations to check = 4.

Bench Mark: FINNMAP BM# 7912 at Kaliakoir

Participants: One surveyor, one Assistant Surveyor and four locally employed workers.

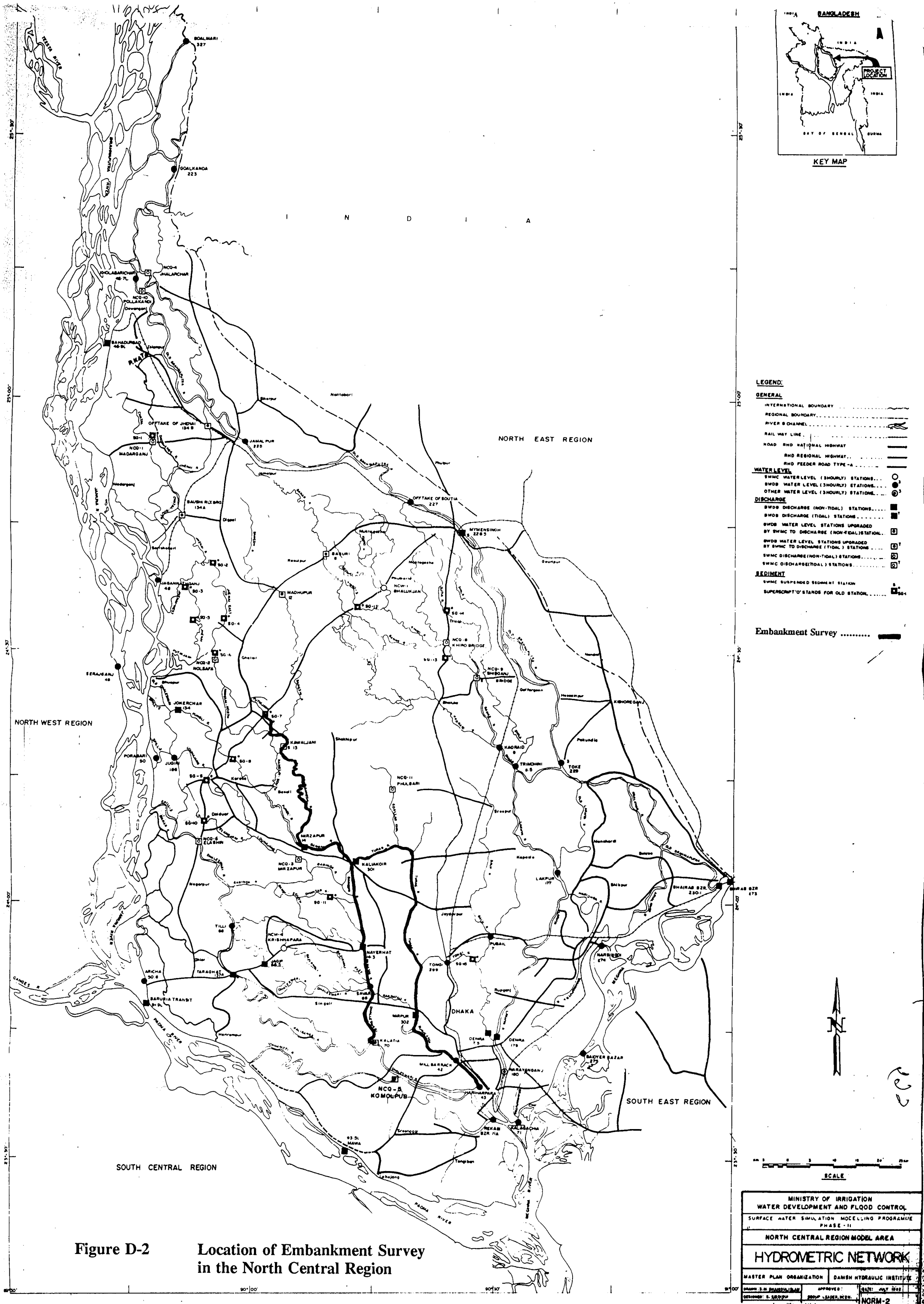
The Schedule Programme

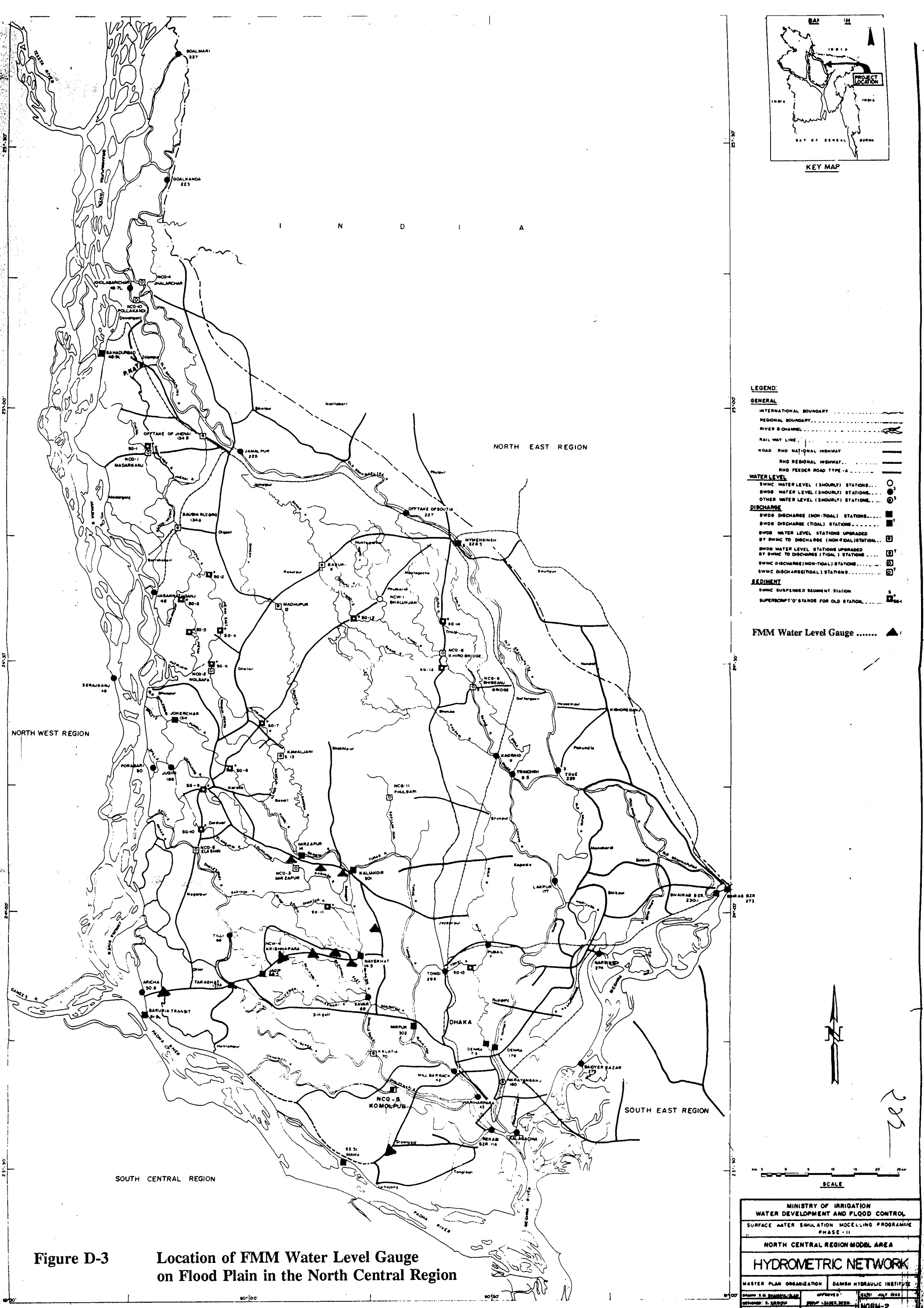
<u>Date</u>	<u>Camp</u>	<u>Work Start-Finish</u>	<u>Remarks</u>
April 04	Kaliakoir		Reconnaissance
05-06	-do-	BM# 7912-AT04	
07-08	-do-	AT04-AT08	
09-10	-do-	AT08-AT12	
11-12	-do-	AT12-AT16	
13	--	--	Camp Shifting
14-15	Shafipur	AT16-AT19	
16-17	-do-	AT20-AT21	
18-19	-do-	AT21-AT22	
20-21	-do-	AT22-AT26	
22-23	-do-	AT30-AT34	
24	--	--	Camp shifting
25-26	Joydevpur	AT34-AT38	
27-28	-do-	AT38-AT42	
29-30	-do-	AT42-AT46	
May 01	--	--	Camp Shifting
02-03	Tongi	AT46-AT50	
04-05	-do-	AT50-AT54	
06-07	-do-	ATT0-ATT4	
08-09	-do-	ATT4-ATT8	Check <u>Tongi Br 299</u>
10-11	-do-	AT54-AT58	
12	--	--	Camp shifting
13-14	Dhaka	AT58-AT62	

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15-16	-do-	AT62-AT65	Check <u>Mirpur 302</u>
17-18	-do-	AT65-AT69	
19-20	-do-	AT69-AT73	
21-22	-do-	AT73-AT77	
23-24	-do-	AT77-AT81	
25-26	-do-	AT81-AT85	Check <u>Millbarrack 42</u>
27-28	-do-	AT85-AT89.5	Check <u>Hariharpara 43</u>





APPENDIX E - PROCEEDINGS OF THE FIRST WORKSHOP

FAP-25: Flood Modelling and Management Flood Management Model First Workshop, 9 - 11 February 1993

INTRODUCTION:

The Flood Action Plan (FAP) aims at the identification, planning, design and construction of high priority flood control projects which are technically, economically, environmentally and socially feasible. The plan follows a staged approach and comprises in total 26 main components and supporting activities. The Flood Management Model (FMM) development is undertaken under the FAP component No. 25.

In undertaking several of the components of FAP, mathematical river models have been developed. These models are indispensable decision support tools for flood management in Bangladesh. They will be central to the optimal operation and management of flood control structures. In addition, they can be employed in the implementation of a program of nonstructural measures such as flood forecasting, flood warning and disaster management. However, based on the capabilities of the existing models and flood management needs a gap has been identified which has to be bridged by a dedicated management tool.

The Flood Management Model (FMM) has, therefore, been conceived as a decision support tool which integrates the Mike 11 based flood modelling system with Digital Elevation Models. Geographic Information System (GIS) technology has been shown by FAP 19 to be a viable tool for managing DEMs in addition to providing advanced graphical and analysis features. The FMM will be developed to provide a decision support tool for the planning, operation and management of flood control and drainage systems on compartment level as well as on regional and national levels. The Compartmental Pilot Project (CPP) at Tangail is chosen for the application of FMM at Compartment level. The regional FMM will be applied to the North Central Region in conjunction with the NCRM Model developed at SWMC. The national level FMM will be based on the General Model developed at SWMC. DEMs for most of these have been developed by FAP 19.

It is obvious that design of such a management tool can only be effective by timely interaction with the model users who will be educated about the technical possibilities of Mike11 - GIS and will also provide feedback to FAP 25 on their decision making needs. During the FMM study it is planned to organize three workshops for the model users, relevant GOB authorities as well as FAP Consultants.

Objectives:

The First Workshop is being organized at the end of the Inception phase. The objectives are to,

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- *develop an understanding of the present modelling capabilities and identify the needs and targets of FMM in relation to flood management decisions in Bangladesh.*
- *present the FMM Concepts and logic developed by the FAP 25 project team, review the draft Inception Report and obtain feed back.*
- *provide an opportunity for dialogue between the modelers, model users, decision makers and individuals affiliated to governmental, non-governmental and research institutions.*

Program :**9 February 1993 : (Tuesday)**

- 08:30 - Registration
- 09:00 - 10:00 - Opening Ceremony
- 10:00 - 10:30 - Coffee break
- 10:30 - 11:30 - **Session I: Flood Management under BWDB**
Chairman: A K M Samsul Hoque, CE Hydrology
1. Planning of FCD Schemes
by: M A Matin, Director, Planning Scheme-I, BWDB
 2. Feasibility Level Design of FCD schemes
by: A N M Wahedul Huq, Ex. Engr, Design I, BWDB
 3. Planning, Design & Operation of FCD Schemes
by: G M Akram Hossain, Design Coordinator, NWH
 4. Flood Forecasting
by: Alam Mia, Director, SW Hydrology I, BWDB
- 11:30 - 11:45 - Coffee break
- 11:45 - 13:00 - **Session II: FAP studies on Planning & Design**
Chairman: M A Rashid, CE SRP
1. FAP - 3, *by: David Milton*
 2. FAP - 4, *by: V. Paramanathan*
 3. FAP - 2, *by: Dr. Afzal Hossain*
 4. FAP - 20, *by: E. Hamel & G. Kibriya*
 5. FAP - 1, *by: Mike West, & O.J. Jensen*
- 13:00 - 14:00 - Lunch
- 14:00 - 14:20 - SWMC Models, Capabilities/Limitations:
presentation by: Dr. R. Galappatti
- 14:20 - 14:40 - Modelling of Flood Control Scenarios (FAP - 25)
presentation by: Emaduddin Ahmad
- 14:40 - 15:00 - GIS / Flood Mapping
presentation by: Bill Syme
- 15:00 - 15:20 - Coffee break
- 15:20 - 15:40 - DEMs and GIS use in Flood Mapping and related activities in
Presentation by FAP 19 (Tim Martin & A. Hassan)

Bangladesh

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- 15:40 - 16:20 - Presentation on Data collection
 T. Martin
 Satellite data/Image processing (*Dr. A M Chowdhury*)

11 February 1993 (Thursday)

- 09:00 - 09:30 - Presentation of FMM - Inception Report
 by: *Guna Paudyal*
- 09:30 - 10:00 - General guidance on the day's proceedings, finalization of
 working groups
- 10:00 - 13:00 Working group meetings
- 13:00 - 14:30 - Lunch
 - Compilation of comments and recommendations of
 working groups
- 14:30 - 17:00 - Final Session (Chairman: Prof. A. Hannan)
 Presentations by working groups, Discussions and
 Recommendations, Response by Team Leader,
 Closing.

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Program for the Inaugural Session

- 08:00 Registration
- 09:00 Arrival of Guests
- 09:05 Tilwat-e-Quran
- 09:10 Welcome Speech by the Superintending Engineer, FPCO
- 09:15 Speech by the Representative, Royal Danish Embassy
- 09:20 Overview of FMM by Team Leader, FAP 25
- 09:40 Inauguration speech by the Chief Engineer, FPCO
- 09:55 Vote of Thanks by Deputy Team Leader, FAP 25
- 10:00 Tea Break

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Final Session

The final session of the workshop was chaired by Professor A. Hannan. The session was divided into 2 parts.

Part 1: Presentations by working group.

Representatives of the working groups presented the discussions recommendations of respective groups.

Group 1 River Modelling: Prof. J U Chowdhury

Group 2 Planning & Design: Kirk Kuykendall

Group 3 FCD Structure Operation: Mustafa Kamal

Group 4 Flood Forecasting: Bramer

The presentations were brief but gave a comprehensive coverages of what was disclosed in the groups. Final comments as well as recommendations of the groups were presented. The summary of the presentations are reproduced in the following pages.

FAP-25 Flood Modelling & Management

Flood Management Model
First Workshop, 9-11 February, 1993

Group 1. River Modelling

Prof. J. U. Chowdhury (Chairman)

Bill Syme (Moderator)

Jahangir Islam (Rap.)

1. Mr. Abdul Khaleque, SE, SWMC
2. Dr. Paulo Larentis, FAP 5
3. Ms. Shahinoor Akhter, SWMC
4. Mr. Larry Bodnaruk, FAP 6
6. Mr. Siddiqur Rahman, FPCO
7. Mr. Yusuf Haroon, BWDB
8. Dr. Mozammel Hoque, IFCDR/BUET
9. Mr. Quazi Saifuddin, FAP21/22
10. Mr. A.M. Shah, RRI
11. Prof. J. J. Peters, PA/FPCO
12. Mr. Shamsuddin Ahmed, FAP 19
13. Dr. Afzal Hossain, FAP5
14. Mr. M. Anwar Iqbal, BARC

Points of Discussion and Recommendation

- * Definition of flood plain - provide recommendations
Area regularly inundated during high river flows.
- * Assessment of momentum transfer to flood plain should be done before finalization of schematization of River network and flood plains. Time dependent schematization should be considered.

This has to be studied on a case by case basis depending on the purpose of modelling.

- * Rainfall-Runoff (NAM) model should implicitly include a routing scheme.

There is an implicit routing of various flow components (e.g., base flow, interflow and overland flow). The calibrated time constants represent an average situation for a catchment.
- * The simulation should include time dependant roughness to model seasonal variations in flood plain roughness.

This can be done .
- * There should be a guideline for rainfall data input when FMM is used for planning and design.

This is available in the NAM model.
- * There should be guidelines for schematization of river network and flood plain system in the case of national, regional and sub-regional model.

Guidelines should be provided by SWMC for national and regional models. FAP25 can provide useful suggestions on floodplains based on the DEM.
- * Comparison of Mikel cross-section (present) with DEM cross-section.

DEM's do not have river cross sections. However comparison of floodplain cross sections from a DEM with that from river surveys could show considerable anomaly due to datum differences and uncertainty of locations. The modeller's experience and judgement are needed in such case.
- * There should be guidelines on quality and quantity of data for Modelling Study.

Yes.
- * Separate flood mapping for agricultural and non-agricultural land.

This is not necessary during flood mapping. Various land types and land uses are needed during impact assessment.
- * Flood duration analysis in terms of the source of flood (rainfall/river flooding).

A flood duration is a combined effect rainfall and river spills. It is not necessary to analyse the durations separately.

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- * Impact of sedimentation on flood plains not addressed in TOR.

This is out of scope of FAP 25: FMM

- * Who is to take over the FMM after completion of the project ?

there are a few candidate institutions, such as BWDB (FF&WC), RRI (SWMC). However, final recommendation will be based on the outcome of FAP 26 and the situation during the final stage of FAP 25.

- * Need of Hydraulic data on flood plain.

Water levels and extent of flooding are the data needed to calibrate and validate floodplain models.

- * Training very important.

Yes, This will be recommended to FPCO and DANIDA.

- * Morphological consequences should be considered.

This is out of scope of the present study.

FAP-25 Flood Modelling & Management

Flood Management Model
First Workshop, 9-11 February, 1993

Group 2. Planning & Design

Prof. Van Ellen (Chairman)

David Milton (Moderator)

Kirk Kuykendall

1. Mr. Badiuzzaman, MIWD&FC
2. Mr. Hassan Ali, FAP 19
3. Mr. Obaidur Rahman, BWDB
4. Mr. Ashfaqui Azam, FPCO
5. Mr. Mojibur Rahman, BWDB
6. Mr. Wahedul Hoque, BWDB
7. Mr. Raihan Ali Miah, WARPO
8. Md. Moksed Alam, LGED
9. Mr. Rafique Ahmed, DAE
10. Ms. Nancy Blum, CARE
11. Dr. Motafa Farooque, DOE
12. Mr. Taher Ahmad, RHD
13. Mr. V. Paramanathan, FAP 4
14. Mr. Emaduddin Ahmad, FAP 25
15. Mr. Mamanul Hoque, CARE
16. Mr. Jim Dempster, POE/FPCO



Scenario Management

Different levels of modelling were defined: General, Regional and Sub-regional. The scenarios at these different levels would be managed and used by different user groups. No "local" level planning & design models will be addressed by the FMM. The connections between the different levels of models will require institutional coordination, for example between BWDB and LGED.

Planning Hierarchy

There are differing views on the structure of the planning activities in Bangladesh. Maybe it is more like a network than a hierarchy? Some felt that plans were proposed at the local level, while others felt centralized planners dictated.

Training

The type of training necessary depends on the type of user. Mechanic, Driver and Passenger were suggested as user groups. The mechanic would need to be trained about computers, the driver would know what the computer can accomplish, while the passenger determines where the computer would take

Sustainability

What happens to the FMM when FAP25 ends? The demand for the FMM must be driven by the user. Regular contacts will be maintained with potential users from the working group to clarify some of the issues and concerns identified during the meeting.

User Needs

This was seen as the fundamental purpose of the working group. The challenge was seen as identifying who would use the FMM so that it could be designed to assist them in their activities. The interests of the public was assumed to be the basis for planning. It was felt the FMM should provide mechanisms so that the interests of the public are incorporated into the planning process.

Why Model?

Planners and designers should be educated about how, when and if the FMM can be used in their jobs. This led to discussion of planning and planning organizations in Bangladesh.

FAP-25 Flood Modelling & Management

Flood Management Model
First Workshop, 9-11 February, 1993

Group 3. FCD Structure Operation

Prof. M. A. Hannan (Chairman)

Johan Crebas (Moderator)

Mustafa Kamal (Rap.)

1. Mr. Finn Hansen, DHI
2. Mr. Egbert Hamel, FAP20
3. Mr. Golam Kbria, FAP 20
4. Mr. Ahsan Ullah, BWDB
5. Mr. Shamsur Rahman, BWDB
6. Mr. Sk. Nurul Ala, FPCO
7. Mr. Masud Ahmad, FPCO
8. Md. Mahboob-Ul-Kabir, SWMC
9. Mr. GM Akram Hossain, Consultant
10. Mr. Sayed Iqbal Khan, FAP 19
11. Mr. Abu Taher Khondekar, BWDB
12. Mr. Enayat Rasul, FAP 25
13. Mr. Enayet Rasul

Points of Discussion and Recommendation

TOPIC - Institutional aspects

DISCUSSION - Organization on regional sub-regional, down to water user group. A good discussion was made about this.

DECISION - There should be some organizations in regional and sub-regional level

TOPIC - Model Operator

DISCUSSION - After the projet will be stopped, who will instructs model operator ?

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- DECISION -** There is a need of central - and sub-committee for training
- TOPIC -** Requirements from FMM
- DECISION -** Boundary conditions are required
- TOPIC -** Monitoring of operation
- DECISION -** Will be done by next higher committee
- TOPIC -** Modelling of Fish friendly structure
- DISCUSSION -** On MIKE11 facilities
- DECISION -** Will be solved by newly developed control structure
- TOPIC -** Flow in 2 directions through structures in MIKE11
- DECISION -** Is already possible
- TOPIC -** Will the operation manual have an example how to run FMM
- DECISION -** Will be produced during projects
- TOPIC -** Is maintenance a part of operation ?
- DECISION -** Yes
- TOPIC -** Possible impact of structures operation on environment
- DECISION -** This is the whole idea of FMM
- TOPIC -** Wrong things in O & M to be strictly overcome
- DECISION -** In the operation guidelines limitations of operations should be given

- TOPIC -** Assess input data quality vs model output
- DECISION -** One needs quality input data for quality output. Measurements should be checked with model results and vice versa
- TOPIC -** Can fuse plug or dedicated Breach be included
- DECISION -** Can be included in a structure operation model, but parameters can not be changed. For this the River Modelling Module is needed
- TOPIC -** Is an Executive Engineer in charge of a project given a tool to instruct operators to operate gates for meeting required water level in the sub compartment ?
- DECISION -** This is right; who can make use of the tool depends on the institutional set-up
- TOPIC -** Risk involved from failure of structure
- DECISION -** Can be simulated by the structure operation module
- TOPIC -** More gauge station to be set-up
- DECISION -** There is an optimal number of gauge stations of which its location is important and they should be well maintained.
- TOPIC -** Allow changing operation rules in 25 years runs
- DECISION -** Operation rules can be changed any time
- TOPIC -** A major problem in the structure operation is due to sedimentation and erosion. This aspect should be considered in developing operation rules.
- DECISION -** Monitoring of siltation should take place and if needed the cross sections in the model should be updated.
- TOPIC -** Breaches in Embankment

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DECISION - Can be simulated by the River modelling Module. If needed, a structure operation model has to be updated.

TOPIC - Operation of Gates in Tidal Area

DECISION - Is possible

TOPIC - Mode of operation: Manual ? Mechanical ? Auto control ? This aspect should be addressed in designing the operation rule.

DECISION - Can be included in the model

TOPIC - Operation of structures to differentiate between Agriculture and non-agricultures.

DECISION - Can be done in the structure operation model

TOPIC - Computer hardware

DECISION - On-site a powerful PC is suggested with extended memory to able to run complex models

TOPIC - Computer software

DECISION - Simplified GIS package is suggested for on-site PC

FAP-25 Flood Modelling & Management

Flood Management Model
First Workshop, 9-11 February, 1993

Group 4. Flood Forecasting

Prof. A. Nishat (Chairman)

Johan Grijsen (Moderator)

Fazle Rabbi (Rap.)

1. Mr. Alam Miah, SHW-II
2. Dr. Galappatti, SWMC
3. Mr. Hafizuddin Ahmad, FF&WC
4. Mr. Saidur Rahman, FF&WC
5. Mr. Yasin, FF&WC
6. Mr. Abdun Noor, FPCO
7. Mr. S.K. Shah, BMD
8. Dr. A.M. Chowdhury, SPARRSO
9. Mr. Sayed Yahya Zaid, CARE
10. Mr. M.P. Gillham, FAP 11
11. Mr. A. Hassan, FAP 19

Points of Discussion and Recommendations

1. Disaster Information System
 - Linkage between FF&WC and Disaster Management Bureau needs to be settled.
 - Sustainability of FAP 25 is to be addressed.
- 2/3. User Requirement and Kind of Information Required.
 - Forecast is required at sub-compartment level (say 100 km²)
 - Storm Surge Model should be integrated with FMM.
 - FAP 25 should carry out field survey in Tangail area to collect the views of the potential users on their forecasting needs.

- A grid of local reference points need to be defined to relate flood forecast to local flooding.
- 4. Necessity of Inundation Forecasting.
 - Better understanding of rain induced flooding is required and hence improved modelling.
- 5. Type of Forecast Desired.
 - Flood (Risk) maps for various flood scenarios are required.
- 6. Level of Accuracy.
 - Different users require different accuracy.
 - FAP 25 should carry out field survey to know from the local people what accuracy they require.

Part 2: General Discussions and Closing

The general discussions followed the Chairman's remarks on group presentations. Several participants raised interesting issues and offered suggestions.

The Team Leader responded to some key issues and thanked everyone. The Chairman closed the session and the workshop.

List of Invitees

Mr. Md. Emdadul Hoque
Joint Chief, Planning
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Bangladesh Secretariate,
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Mr. Khawaja Abdur Rahman
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Mrs. Ismat Ara Jahan
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Mr. Obinash Chandra Sarker
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Mr. A K M Shamsul Hoque
Chief Engineer
Hydrology
BWDB
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